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THE TECHNICAL STUDENT'S INTRODUCTION TO THE GENERAL PRINCIPLES OF MECHANICS.

LAWS AFFECTING NATURAL PHENOMENA—MATTER AND MOTION.

CHAPTER XXVII.

AT the end of last chapter we stated that grave errors in mechanical construction were frequently made through overlooking the great principle that motion is always in straight lines; and that we should illustrate a few points in connection with fig. 26.* This we now proceed to do. If a carriage, *a*, be drawn up rapidly in the direction of the arrow *b*, and through forgetfulness on the part of the driver the corner is approached too nearly,—and if to avoid the crash the horse is suddenly pulled to the right, to go in the direction of safety by arrow *c*,

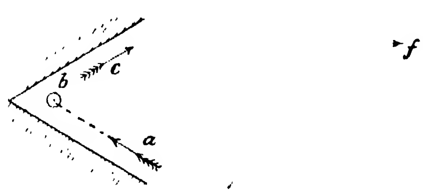


Fig. 26.

—the tendency of the carriage *a* to go in a straight line carries it still forward in direction *b*, while the horse is pulling strongly in direction *c*, and the result of the mistake in driving will probably be that the carriage is overturned. This principle is illustrated in the laying out of watercourses, and in the junction of pipes for conveying water, or conducting steam or air at pressure, or the flues of boiler or other furnaces. Thus, if the watercourse be made with a sharp corner at *d*, where the flow of the water in original direction at arrow *e* is changed suddenly in direction *f*, the tendency of the water to flow on in a straight line carries it to the corner *d*: and this, if soft earth or soil, is worn rapidly down, or if it be hard and rocky, eddies and cross-currents are created in the flow of the water before it can get steadily into the new direction *f*; and all eddies or cross-currents thus created tend to impede the regular flow of the water; for we put two antagonistic forces in action —the tendency of the water to go in the direction of *e d*, and the tendency of the fall or flow of the water downwards in the direction of *f d*. The same holds true of inclosed channels in which liquids flow, as water or drainage matter: and with regard to this last-named art, it is difficult to say what was the extent of the sanitary evils produced, or that of the hindrance created to rapid progress in the practical drainage and sewerage of our streets and houses by the system so long adhered to—and it is by no means done away with yet—of making the junction of a branch sewer or that of a house drain to a main sewer, as *a*, fig. 27, at right angles to the main sewer *b b*, the direction of flow of liquid in it being as at arrow shown. The force of the flowing liquid along it sent it to impinge against the side of

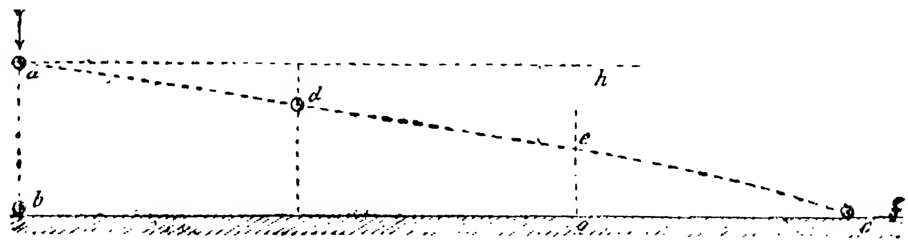


Fig. 25.

* In p. 260, last vol., we referred to this fig. as 24; this should have been, as now stated, 26, and the reference to fig. 23 in last line of p. 259 should be 25.

sewer opposite, tending rapidly to wear out the mortar in the joints of the brickwork at that point, and, what was worse, stopping or impeding the flow of the sewage, and thus causing deposits of solid matter at or near the point of junction, which deposits tended to—and in thousands of cases actually did—stop up the sewer. And in the conducting of water along pipes, not a few mechanics have been placed in difficulties by giving junctions, and also by changing the directions of the main flow, arranged on this erroneous system of making them absolutely antagonistic to each other—as the flow of the liquid along the junction, as *a*, strikes, so to say, that flowing down *b b*, so as to throw it aside. In all cases where liquids are conducted along channels or tubes, when any change in the direction of the flow or current is to be made, the tendency of the liquid to go in the original line of its flow should be gradually and not suddenly overcome; and this is best done by giving a curve at the point where the change is to be made, as at *c*, between the two antagonistic or opposite directions of *d* and *e*. And the larger the radius of this curve the more easy will the change in direction of flow be made; in all cases there will be a lessened flow or rate of current in proportion to the number of changes. The fewer the better of these; but in many cases circumstances compel numerous ones: all the greater reason, therefore, to be careful how they are laid out. And this carefulness is all the more necessary where the mechanic has to deal with fluids which are muddy, carrying matters in deposit—frequently the case in industrial work. For every disturbance in the current tending to stop or to reverse it, or to make it more sluggish, brings about deposits of the solid matters held in suspension. And these deposits become in time causes of further changes in and a retardation of the flow, and have been found in scores of cases so difficult to be dealt with that large expenditure has been incurred by having to take down or up and repair the channels. While attending to the main channel or tube, all junctions to it must also be designed on the correct principle we have pointed out. The worst of all forms we have illustrated at *a b b*; a very much better form we show at *f g g*; and the best of all, that which is now the practice in the most carefully designed works, at *h i* in fig. 27. The mechanic has also often to deal with the conducting of air, either cold or hot, or with heated gases from furnaces in tubes or channels or flues; and the law we have now under notice affects the flow of gases and air along channels as it affects that of liquids. For although, as we have seen, the popular mind has a difficulty to grasp the fact, yet common air, for example, has in reality the attributes of a solid body, and can offer resistance to bodies moving through it, or to a solid body it comes in contact with when itself in motion. In the flues, for example, of a steam-engine boiler furnace, the great object is to maintain the draught with regularity, and thus as uniformly as possible. All changes in the direction of the current or line of draught made abruptly affect its flow; and the loss incurred arises not so much from the mere retardation of the speed, as in the deposit of soot and the fine particles of ashes carried along with the heated air, which deposit is just as much the result of the disturbance of the flow of the current as is the deposit of solid matter from a muddy liquid carried

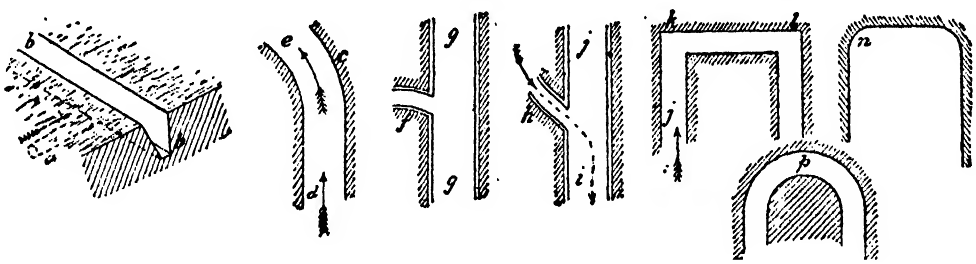


Fig. 27.

along a similar channel. Thus, in the case of a "return" or a "wheel" flue, as at *j k l*, fig. 27, the sudden changes in the direction of the current or flow in line of draught, at the corners *k* and *l*, will give rise to such eddies and retardation, that the soot deposits will so rapidly increase that it may only be by repeated and therefore costly clearings-out of the flues that the draught of the furnace can be maintained with the desired efficiency. All this may be avoided by giving the flue a continuity of direction as nearly approaching a straight line as possible, and this by curving off the corners as at *n o*, or better still by making, if the plan will admit of it, the sweep or complete curve as at *p*. This straight-line motion is that which is aimed at in all flued boiler design; but in many of the forms which have been patented—some of which have presented most curious complications in the forms or shape of the internal flues or tube-flues—what saving has been expected by utilising the heat of the gases passing from the fire grate to the chimney flue has been lost by the errors made in the design, not so much in overestimating the economical effect of internal flues

—which, however, is frequently done—but by the shape or form and the position given to these, in forgetfulness or ignorance of the law now under notice. Some may fancy that mistakes so glaring as that exemplified in fig. 27, at *j k l*, could not be perpetrated; but we have had to deal with cases as bad, if not worse, if worse could be. And we have seen that in the case of drainage mechanics as glaring a mistake has been made by hundreds of artificers, and that through a long course of years. Under this head all these illustrations have been presented to the youthful student in mechanics, not altogether in view of the important special lessons of a practical kind they are calculated to convey; but also with the object, in one sense not much less important, of leading him into that habit of careful thought which enables him not merely to understand as far as may be the peculiarities of a natural law, but to think of subjects from all points of view, or "all round," to use the graphic expression more than once employed in these pages—in that close and direct way which, perhaps more than any other faculty possessed by the mechanic, secures to him that success in his work which we suppose him to be ever striving to obtain.

Motion in Curved Lines.—Centrifugal Force.—Circular Motion, or Motion round an Axis or Centre.

We have seen by preceding paragraphs that the natural tendency of all moving bodies is to go on in straight lines, as the natural tendency of motion is to be uniform—that is, to pass through equal spaces in equal times. But just as this uniformity in motion, if changed, must be changed by some force other than the original force which set the body in motion, so the natural straightness or directness of that motion, if changed — that is, bent or deflected — must be the result of some other force. Motion in curved lines produced by a given force may be said to be of two kinds. First, that in which continuity in the sense of length is its characteristic—as extending, say, from point *a* to *b*—which line is called the path of motion (see fig. 28). Second, that in which the direction of the curve is changed more or

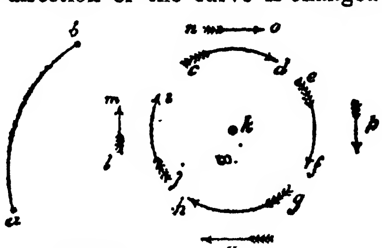


Fig. 28.

less frequently—as, for example, the motion may go from *c* to *d*, then from *e* to *f*, then by the force be changed so as to go from *g* to *h*, then from *j* to *i*. Here the paths of movement of the body are such that, beginning at point *c*, it goes—or rather is compelled by a superior force to go—round by *e f h*, till it finally returns to the same point *c* from which it started. When a point or a body moves thus in a line which "returns into itself," to use the

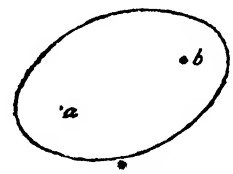


Fig. 29.

ordinary phrase, the path of the motion is a "circle." If any point and all the points of it are *equidistant* from a given point, as *k*, this point *k* is called the "centre"; and in relation to solid bodies with curved surfaces, such as cylinders, cones and spheres, the point *k* is called the "axis." If the body or point move, or is compelled to move in a series of curved lines which, taken as a whole, "returns into itself" in a *continuous* figure or outline other than that of a circle, that figure is the "ellipse"—popularly called the oval; the body or point revolving, so to say, round two points (*a*, *b*, fig. 29) called the "foci." The elliptical path of motion is that of the movements of the celestial bodies; the circular path is that with which we are most familiar, being that of by far the greatest number of bodies which move in curved paths or lines,—it may, indeed, be said to be the only curved movement we use or see examples of around us.

We have elsewhere alluded to the fact that a circle is in fact a polygon made up of an infinite series of straight lines, the direction of which, as in the lines of all polygonal figures, is continually changing. This explains or illustrates the relation of the curved line, as *c d*, fig. 28, which a body is compelled to take, to the straight line, as *n o*, which path, as we have seen in preceding paragraph, is the one in which a body acted upon by a force at the point *n* has a tendency to go, and is, in fact, the natural path of motion, which is not acted upon by any force or forces disturbing the primary force. The arrow *q* represents the straight line in which it is the tendency of the body acted upon by a force, as at feathered end, to move,—and so on with the other lines. The student will perceive readily enough that at each change of direction in the sides of the polygon which we have seen a circle to be, a force must act at each corner, so to say, with power sufficient to "drag round" the body moving along from *n* to *o*, fig. 28, so that it will take the direction of line *p*. And the student, remembering that the polygon or circle is made up of an infinite number of sides, will see that this "dragging round" is going on at an infinite series of points—practically speaking,

at every point in the curved line. This dragging force may be given in a variety of ways; but the most familiar example we have of a force producing a circular movement the path of which is constantly "returning into itself," round and equidistant from a given point, is the swinging of a heavy body, as a stone suspended, say in a sling by a cord or band held in the hand. We need not at present enter into any consideration of intricate points connected with the "moving force." Every schoolboy is familiar with the fact that by his bodily exertion, or rather by the muscular force of his arm, he can keep the stone in a sling in rapid movement round his hand. And the path of this movement he can, so to say, adjust in such a way that it will assume different positions in relation to his body. He may give it a horizontal path round and above his head, which path will be at right angles to his body or parallel with the ground; the path he gives it may be parallel to the length of his erect body, or at right angles to the ground; or he may so swing it that it may be oblique to his body or the surface of the ground he stands upon. The schoolboy may and often does all this, but he does it intuitively and without thinking; but if the young mechanical student will not disdain to use and to experiment with so familiar and simple a "philosophical instrument" as a boy's sling is, he will, by patiently thinking out what his different twirls are, receive some lessons as to "circular motions" the value of which in his after duties in workshop practice he will then fully acknowledge. In patiently analysing as best he can—and facility of analyses of these kinds will come to him with continued practice—these movements, he will in one of them be almost bodily sensitive to the fact that he is actually dragging round the sling at each change in the direction of its motion—as, say, at the curve *c d*, fig. 28. He feels that this dragging force which is exerted by his hand, wrist and arm, is absolutely necessary to counteract some influence which he may be said to know intuitively tends, and that more or less but always powerfully, to take the stone in the sling *out* of the curved or circular path in which by the force of his muscles acted upon by his volition or will he can alone maintain it, and send it in some straight-lined course, as *n o*, *p*, *q*, or *l m*.

Centrifugal Force.

Now, in this influence, of which he is perfectly conscious, the young reader becomes acquainted with a physical force of a most important kind in mechanics, and which, although actually concerned with or arising from the very circular or curved motion he is, so to say, creating by his muscular force or exertion, is in itself a striking exemplification of the physical or natural law explained in the preceding paragraph—namely, that all motion is in straight lines. He can, while swinging the sling quickly round, have a very striking example of this natural tendency of moving bodies; for he has only to let go one of the two cords of his leather sling, thus releasing the stone embraced by it, when it quickly darts forth from it and proceeds or "flies" from him in a straight line, as above named. That this line is straight even the schoolboy soon learns to know, and so to depend upon the accuracy of the direct line that, by dint of a little practice, he can so aim at that he can strike a body at some distance from him with the stone which he releases from his sling. In ancient times the sling was an effective instrument of warfare; and in the "lasso" of the South American herdsman, which is a long cord and terminated with a loop, we find another way in which this tendency is made practically useful,—for after whirling the loop round his head he at a certain moment lets it go, when, leaving its circular path, it darts off straight to its destined point—the head or horns of the buffalo or ox which it is the object of the herdsman to catch. Returning to the experiment of the youthful student with the sling: of the two forces, of which he is now cognisant, present in its movement, he feels that one is that of his wrist or arm in constantly dragging round the stone—"forcing it," to use the popular yet most suggestive phrase, to travel in a circular direction; and the other that which, if left free, forces it to go off in a line perfectly opposite to that of the curved one—that is, in a straight line. This "force," which is found to exist in all bodies compelled to move in a circular direction, is that to which the name of "centrifugal" is given. Centrifugal force is, then, that which is prompting, so to say, all bodies so moving to fly away from or leave the centre, and this always in straight or direct lines. The term is derived from two Latin words, *centrum*, a centre, and *fugere*, to fly—so that this force may be defined as a "centre flying" or "leaving" one. The opposite or converse "force"—namely, that which compels a body to seek or move towards the centre—is called "centripetal," from two Latin words, *centrum*, and *petere*, to move forward or towards. The force, such as that of the muscular power of the body in the case of the sling, which drags round the body, compelling it to leave the natural straight line, is the "centripetal force"—while, when the sling is released and the stone left free to move, it is the "centrifugal" force which by its action sends forth the body in a straight line, the length of which and the velocity with which it moves along it is dependent upon the velocity of the body while it was compelled to move in a circular direction; and the momentum or force with which the stone strikes the body aimed at is dependent upon its weight or mass and its velocity forward.

THE GEOMETRICAL DRAUGHTSMAN.

HIS WORK IN THE CONSTRUCTION OF THE FIGURES AND PROBLEMS OF PLANE GEOMETRY, USEFUL IN TECHNICAL WORK.

CHAPTER XV.

AT the conclusion of the preceding chapter, we began to describe the method of obtaining a nonagon within a given circle. We now conclude this by the following. Join the centre *a* to the point *g* by a straight line,

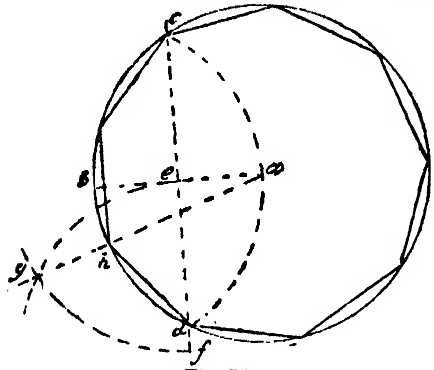


Fig. 75.

which will cut the circumference at *h*: we obtain thus the arc *d h*, which will be nearly the side of the inscribed nonagon, and which is taken and set off nine times round the circumference of the circle. Each angle of the regular nonagon is equal to 140°.

The "decagon," or ten-sided polygon, is illustrated in fig. 76, which also illustrates the method of inscribing the figure within a given circle. To obtain the side of the inscribed decagon, divide the radius into

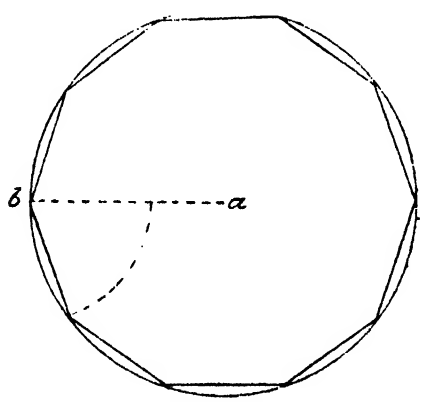


Fig 76.

mean and extreme proportions. The largest division obtained will be the side of the decagon, which will divide the circumference exactly into ten parts, if set off from the point *b*.

Divisions or sides of the inscribed decagon may be obtained by first dividing the circle into five equal parts, by the method shown in fig. 1, Plate CCXV. Then dividing each arc into two equal parts, we obtain the ten points of the angles of the decagon. Each angle of the regular decagon is equal to 144°.

The "dodecagon" is a twelve-sided polygon. To find the twelve points of the angles of the inscribed dodecagon in fig. 77, first carry the radius, *a b*, six times round the circumference; then divide each of

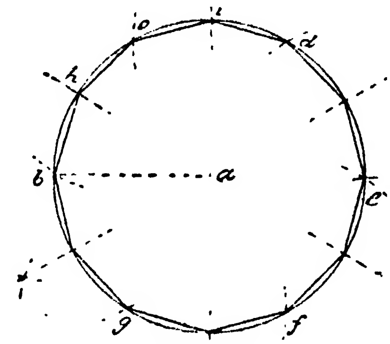


Fig. 77.

the six arcs, as *b c*, *c d*, *d e*, *e f*, *f g*, and *g h*, into two parts, as at *h* and *i*; and in this way the twelve points of the regular inscribed dodecagon will be obtained, which join by lines, as in the diagram. Each angle of the regular dodecagon is equal to 150°.

The method of finding by approximation the side of any regular inscribed polygon may be as follows:—Suppose that we wish to obtain the side of the nonagon as in fig. 5, Plate CCXV. Having divided the diameter, *a b*, of the circle into as many parts as the polygon which we wish to obtain has sides, from the points *a* and *b* as centres, and with a radius equal to this diameter, we determine by two arcs the point of intersection *c*. Through this point, and the second division, *d*, of the diameter, draw the straight line *c e*; the chord *b e* of the arc *b f e* will be the side of the polygon wanted.

We may also obtain the summits of the angles of

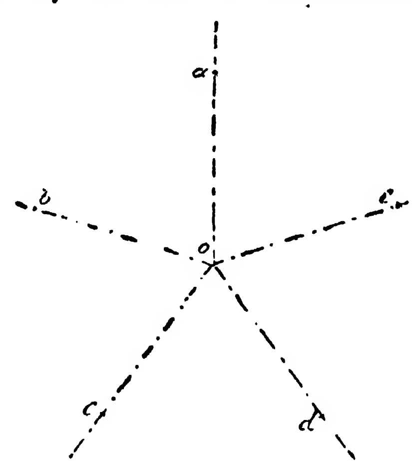


Fig. 78.

any regular polygon by the method illustrated in fig. 78. If, for example, we wish to obtain the five

points of a regular pentagon, we take the circumference as 360°, and, by dividing this number by five, we obtain 72° as measurement of each of the five angles, which we draw round the point *o*, thus giving equal lengths, *o a*, *o b*, *o c*, *o d*, and *o e*, to the five radial lines of these angles, and we obtain the five points of the angles of the regular pentagon.

"Irregular polygons" are those figures the sides or angles of which are not equal, as in fig. 79. To describe an irregular polygon, divide it into triangles,

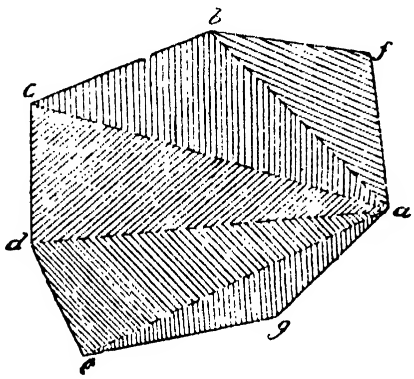


Fig. 79.

drawing lines from one of its diagonals (as from *a* to *b*, *c*, *d*, and *e*) to all the others. There will always be as many triangles as the polygon has sides, less two. This being done, draw each triangle successively in the same order as the copy, by the same method which has been given to construct the scalene triangles.

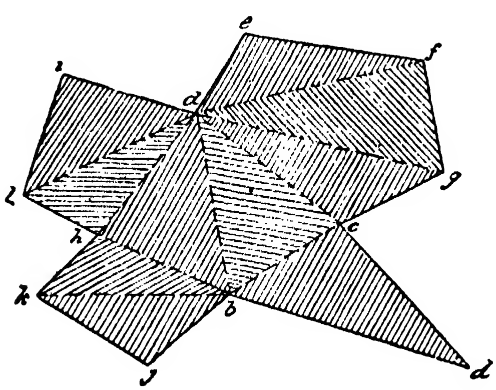


Fig. 80.

The surface of every irregular polygon is equal to the sum of the surfaces of the triangles which compose it, as the angles *a f b*, *a c b*, *a d c*, *a e d*, and *a e g*. The sum of the angles of a polygon is equal to that of as many times two right angles as there are sides, less two, in the polygon.

Irregular polygons with re-entering angles.—To copy or measure any irregular polygon with re-entering angles, as in fig. 80 in text, divide it into triangles, which draw in the same order if it is to be reproduced, or which measure if the same surfaces are to be set out anew. The triangles into which the figure is then divided are as follows: *a b c*, *a e f*, *a f g*, *a g c*, *b c d*, *b j k*, *b k h*, *l h a*, *l i a*.

To construct a polygon equal to a given polygon.—First, by decomposition into triangles. This decom-

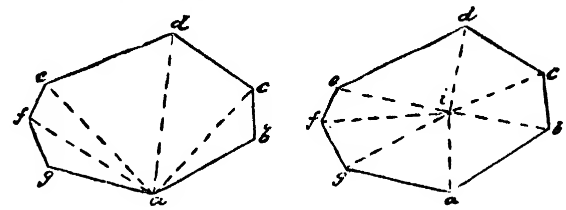


Fig. 81.

position may be effected in different ways: either by joining a summit, *a* (fig. 81), of the polygon to all its other summits, as already shown, or by taking any point *i* and joining it to all these summits. It is only necessary then to determine in succession each of these triangles, and to reconstruct these triangles one after the other. In the diagram in fig. 81 we suppose that we have taken no other dimensions than those of the lengths of the sides, and of the diagonals *a c*, *a d*, etc., or of the lines *i a*, *i b*, *i c*, etc. This method of decomposition offers, from a practical point of view, a very serious disadvantage; for we are obliged to build, as it were, triangle upon triangle, in such a way that, if there is a large number of them, the last may be burdened with all the mistakes made in the preceding ones, and their position be thus considerably altered. For it is to be noted that, however small the mistake made in measurement may be at first, this increases in such a rapid ratio that the error will be very serious at the conclusion of the construction.

The following method does not present this disadvantage: it allows us, on the contrary, to determine separately each point of the polygon, so as to render the position of any one independent of the errors

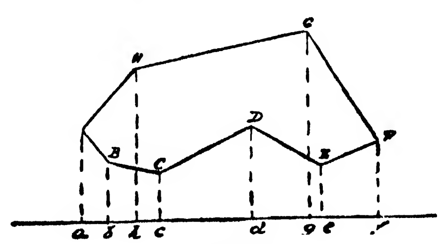


Fig. 82.

which have been made in finding the position of the others. This method is by decomposing the figure into a series of trapezia. Let *a b c d e f g h* (fig. 82) be the polygon given, which is to be reconstructed. Draw in the plan of this polygon any line whatever, to which give the name of axis; and upon this line drop

the perpendiculars A *a*, B *b*, C *c*, D *d*, etc. Measure these perpendiculars, and also the distances *a b*, *a h*, *a c*, *a d*, etc. Each point of the polygon may then be put in its place by drawing, at a convenient part of the paper, a straight line, as *a f*, and setting off upon this from any point, as *a*, lengths *a b*, *a h*, *a c*, *a d*, etc., and by raising, at the different points thus obtained, perpendiculars A *a*, B *b*, H *h*, C *c*, etc., equal to the lengths previously measured. It only remains, in order to finish the construction of the polygon, to join the points thus obtained in succession.

In concluding our constructions or problems in connection with straight-lined figures, as polygons, we deem it necessary to explain certain terms and expressions which are often confounded with one another, and give rise to ideas in the minds of students of geometrical construction. We shall endeavour to give here the exact definitions of the following expressions: "equal figures," "symmetrical figures," "similar figures," and "equivalent figures," all of

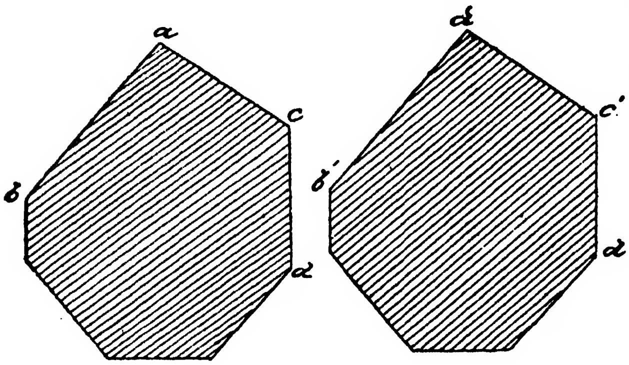


Fig. 83.

which are popularly supposed to be synonymous, meaning the same thing, which they do not. First as to "equal figures." Equal figures are those which have the angles and the sides equal and placed in the same direction, as in fig. 83. Two equal figures placed one upon the other should coincide perfectly—that is to say, they should cover each other exactly, without any part of either extending beyond the other. It follows, therefore, that equal figures have the same surface. Second, as to "symmetrical figures." We call those figures "symmetrical" which are equal, but whose equal sides and angles are placed in a contrary direction, as in fig. 83 if we suppose the side *d c* was to be placed where the side *b* is—that is, side *c'' d'* to the right and *c d* to the left. The two hands, the two feet, and all the double organs of man are symmetrical figures. Symmetrical figures are equal in surface. Third, as to "similar figures." We call those figures similar which have all their angles equal each to each, and the corresponding sides proportional, as in fig. 84. Similar figures may be very different in surface. In similar figures we call those angles homologous which are equal each to each, and those sides homologous which join the points of two homologous angles. Thus the angle *a* (fig. 84) is homologous to the angle A; the side *b c* is homologous to the side B C. Fourth,

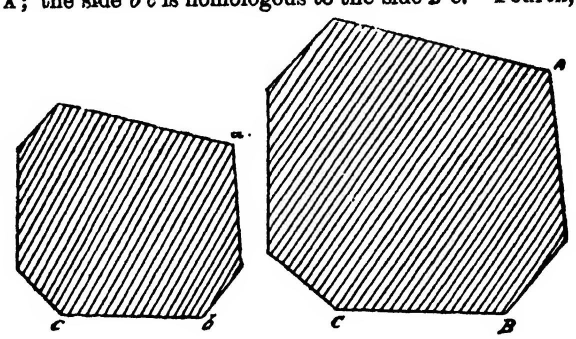


Fig. 84.

as to "equivalent figures." These are figures which have the same area or extent of surface, as in fig. 85. Two equivalent figures may be dissimilar as to their forms: for example, a triangle may be equivalent to a square, to a rectangle, etc. Thus, the surface of a meadow in the form of a parallelogram three acres

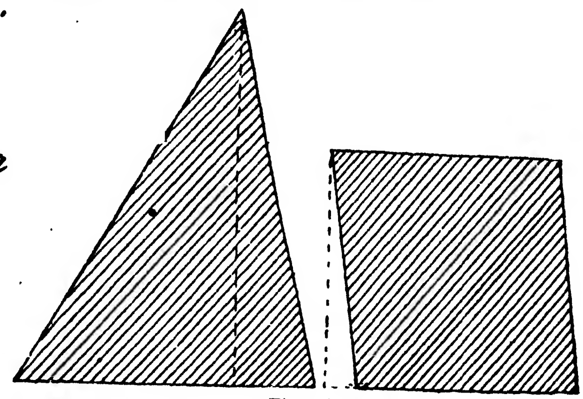


Fig. 85.

in extent would be equivalent to that of a piece of ground in the form of a triangle if, in this triangle, the base multiplied by the half of the height gave us a number of square yards equal to three acres.

The points connected with the problems on right or straight-lined figures are of great practical importance, as much of the work of the constructive mechanic depends upon drawings in which mere surfaces or what are called forms, shapes, or figures are concerned. With these he is working daily; and in the rough-and-ready method which many artificers adopt, not only as to constructing or forming them, but in estimating the extent of their area, though they may be ignorant of practical geometry, they are working out unconsciously many of its problems and methods. These forms and figures, and those about to be described, are also of great use in many of the larger operations of the land surveyor and the architect.

THE CALICO PRINTER.

THE CHEMISTRY AND TECHNICAL OPERATIONS OF HIS TRADE.

CHAPTER XVIII.

Vegetable Colouring-Matters (*continued*).—Litmus.

THIS dye is prepared in a somewhat similar manner to orchil, but with the addition of pearlash, from the lichens *Roccella lecanora* and *variolaria*, which grow on the coasts of Norway, Sweden, and the Canary Islands. The blue pulp so obtained is dried, and constitutes the litmus of commerce, as an indigo-blue cake, which readily dissolves out a blue liquid with water or alcohol, which turns red on the addition in excess of an acid, and blue again on adding excess of an alkali. Hence it is largely used in the laboratory as a test for acidity and alkalinity. It is not used in calico printing, except in rare cases, when an unfixed violet is obtained by printing on the thickened neutral aqueous solution.

Persian Berries.

This important dye-ware is the seed-bearing fruit of the buckthorn, and of several other species of the genus of shrubs *Rhamnus*, growing in Persia, the Levant, Roumania, and various parts of southern Europe. The berries are about the size of peas, and are marked with semicircular depressions; they are of yellow or green or black colour, according to age. The latter are generally deficient in tinctorial properties, as are also those of too yellow a shade. They should be collected unripe, or when they have attained a greenish-yellow colour. They are brittle, and when broken of yellow colour; they emit a peculiar odour, and are of bitter taste. They contain several compound bodies, but the essential colouring principle is a glucoside termed rhamnin by Lefort ($C_{12}H_{12}O_5 + H_2O$), which dissolves out slightly in cold water, but readily in hot water or alcohol. This body, which is the valuable principle in berries, crystallises in yellow silky needles, and is probably identical with the colour contained in quercitron bark. On treating berries with boiling water a yellow-greenish solution is obtained, which is the liquor that is used in dyeing, etc., and exhibits the following properties: dilute alkalies turn it orange; dilute acids give a slight precipitate; alum yields no precipitate; acetate of alumina boiled gives a splendid bright-yellow precipitate, which is the colour made use of in calico printing and dyeing; gelatine on boiling gives a flocculent precipitate; lime-water turns greenish and forms a slight precipitate. Persian berries yield a bright yellow with alumina mordant; yellow with tannic acid; orange-yellow with tin; olive-green with iron. The aqueous extract (which when dried constitutes the *rhamnine* of commerce) is used chiefly in calico printing to produce a yellow with acetate of alumina, and a green with aniline blue or aniline green, and also a green by printing and steaming with prussiate of tin.

Bark or Quercitron.

This is the inner bark of various species of trees belonging to the natural order of *Amentaceæ*, known as *Quercus nigra* or black oak, *Quercus digitata*, *Quercus tinctoria*, and *Quercus trifida*. The black oak, which yields the bulk of the bark in the market, is a tree twenty-five to thirty metres high, which grows in the forests of Pennsylvania and other parts of the United States. The epidermis, which is black, is removed, and the bark is ground or rasped, and is ready for the market, or for conversion into extracts. These, as in the case of logwood, are made by extracting with water and evaporating down to the desired strength.

Ground or chipped bark of commerce is a rough powder of yellow or buff colour, which yields with water a yellow liquid, which dyes up cloth properly mordanted with alumina, yellow; with tin, orange; with iron, olive, darker than in the case of berries—or when a stronger mordant and liquor are used, a black. The aqueous solution is turned orange by alkalies; it is not much affected by acids. In calico printing ground bark is used for dyeing yellow or olive upon alumina, tin, and iron mordants.

Extract of bark is a dark-brown liquor or syrup, largely used in printing, generally in conjunction with logwood extract in producing a black, with acetates of iron and chrome.

The tinctorial principle of bark is *quercitrin*, which closely resembles in properties *rhamnin* of berries. It contains, however, a large percentage of another body—namely *querci-tannic acid*, which is the chief cause of the deep-black colour obtained from bark with iron or chrome.

Flavine is quercitron bark prepared by a special process whereby a yellow powder is obtained, which yields very bright and fast yellows with tin and alumina mordants. It is much stronger than the bark, for the first-class flavine contains ten to sixteen times as much colouring-matter as bark. The best quality is manufactured in America, but a considerable amount is made in England by the following process:—Two tons of bark are mixed with four tons of water; 2 cwt. of oil of vitriol is added, and steam is passed into the mixture for twelve hours. It is then run upon woollen filters, and washed with water until all the acid has been removed; pressed, dried, and served. Flavine may thus be said to stand in the same relation to bark as garancin does to alizarine. For use in printing flavine is extracted with boiling water, the insoluble matter settled out, and the aqueous solution

evaporated to the desired strength. It is employed for dark-yellows, oranges, and olives.

Weld.

This dye is the extract of a dried plant known as *Reseda luteola*, a small herb cultivated in various parts of France, Germany, and Austro-Hungary, and formerly grown in this country. The weld plant is sold in sheaves like straw, of a yellowish colour—which on boiling under pressure with water, or by extraction with alcohol, yields the weld extract of commerce. Extract of weld may be used for the same purposes as berries in printing,—namely, the production of yellow, alumina and tin being the mordants,—but has fallen into disuse.

The colouring principle of weld is named *luteolin*, which dried at 150° has the formula $C_{12}H_8O_5$, and is a yellow substance crystallising in needles, which are slightly soluble in water, soluble in alcohol and ether, or boiling acetic acid.

Fustic (Yellow Brazil-wood, Cuba-wood).

This dye-ware is the decorticated wood of *Morus tinctoria*, a tree growing wild in various districts of India, and in Mexica, Cuba, Jamaica, and some parts of South America. The wood, which is of canary-yellow colour, is sold generally as a coarse powder, or in chips, which having a "fermentation" similar to that of logwood, readily yields on treatment with water pale-yellow liquid which dyes alumina-mordanted cloth yellow, closely resembling that obtained with quercitron bark, and resembling the latter dye in most other respects. It contains two colouring principles, or rather modifications of the same, named *morine* and *morein*—the former readily passing into the latter modification by oxidation.

Fustic is used for dyeing both cotton and wool yellow. The fustic liquor and extract of commerce are extracts of the dye obtained by boiling with water and evaporating down. They are used in printing similarly to quercitron bark, both for yellows and combined with logwood blacks. They are also employed for making yellow carmine or lake, also red fustic lake.

Aloes.

This is the dried juice of different species of the *Aloe* genus of plants. It was formerly used in dyeing, but has now been superseded; it yields indifferent shades of yellow, pink and purple on silk and wool, and rather poorer shades on cotton mordanted with tin, alumina, etc.

Turmeric.

This is the yellow or buff coloured chipped or rasped tuber or underground stem of the *Curcuma tinctoria*, a plant belonging to the *Scitamineæ*, which grows in some parts of China and India. The commercial product mostly comes from Bengal and Java. Boiling water, or cold alcohol, or ether, or the fatty and essential oils, extract a yellow-coloured liquid which has the characteristic property of readily changing to a red-brown by alkalies, and returning again yellow on addition of an acid. It dyes up wool and silk a beautiful but fugitive golden yellow, and cotton a bright but also very loose yellow. The alcoholic solution may be printed on cotton without a mordant, and after steaming or ageing, slightly attaches itself to the cloth; cold dilute soap turns it red-brown, and daylight soon destroys the shade. Turmeric is used in the laboratory as a test for alkalies.

Annatto (Anotto, Rocon, Bixin, Orleans).

The fruit of a South American shrub named *Bixa orellana*, is surrounded with a pulp, which after "fermentation" is dried and constitutes the annatto of commerce. On treatment with water a yellow liquid is obtained, containing a yellow colouring principle termed *orellin*. This solution dyes up cloth mordanted with alumina a fine bright yellow; the residue, however, yet contains a tinctorial body named *bixin*. Indeed, the chemistry of annatto is not thoroughly understood: it contains several complicated substances the exact tinctorial properties of which has not been fully ascertained. In printing with annatto caustic soda is used as the solvent of the colouring principle. 1 lb. annatto paste is boiled with $1\frac{3}{4}$ gill caustic soda at 18° T. After thorough boiling 1 oz. tartaric acid is added, and 6 oz. ground alum; these ingredients are well mixed, thickened with starch and British gum, printed, steamed, and washed. A bright orange-yellow is obtained, which resists soap and light moderately well, and rapidly fades in the sun.

Catechu (Cutch, Gambier, Terra Japonica, Cashew).

Under these and other names are known a variety of vegetable preparations which are largely used in printing and dyeing for obtaining various shades of black, brown, and chocolate. These dye-stuffs, sometimes termed astringents (see the "Cyclopædic Technical Dictionary"), consist of the dried aqueous extract of a great variety of plants, and contain tannic and gallic acids and several colouring bodies closely allied to those two substances. Genuine catechu is obtained from the wood of *Acacia catechu*, a tree belonging to the Leguminosæ, division Mimosæ, and growing in Hindostan and the Indian Archipelago.

Theory of the Use of Catechu in Dyeing and Printing.—Catechu contains (1) a variety of tannin named *catechu-tannic acid*, an amorphous, colourless tannine, which dissolves in cold water, and is thrown down by gelatin, and also as a dark greenish precipitate by persalts of iron. According to Dr. Davy, Bombay catechu contains about 50 per cent. of this body.

THE COLOUR MANUFACTURER.

WITH PRACTICAL NOTES ON THE USE OF PAINTS AND DYES IN DECORATIVE WORK.

PART FIRST.—PIGMENTS.

CHAPTER X.

The Chemistry of Copper Compounds.

In continuation of this paragraph, begun at the end of our preceding chapter, we have to state that it is to the class of salts formed by cupric oxide that most copper-green pigments belong. They possess the remarkable property of being almost colourless in the anhydrous or dry state, but green or blue when in the hydrated condition or united with a certain proportion of water. Hence, when green copper pigments are heated but slightly, they lose their colour; and they frequently alter in shade very slowly by mere prolonged exposure to the air. Light has also a destructive action upon many copper pigments, the action undoubtedly being simply the escape of the water of hydration. The principal compounds of copper which are insoluble, and to which belong copper pigments, are (1) various *basic* salts, also termed *oxy*-salts, as the oxy-chloride, $Cu_3O_2 \cdot Cl_2 \cdot (H_2O)_4$, which is a light-blue compound formed as a green precipitate, when cupric chloride is decomposed by an excess of caustic soda. It occurs native as *atacamite.* Several basic sulphates exist; thus, by subjecting sulphate of copper to a gentle ignition for several hours, an orange-coloured powder is obtained, Cu_2SO_5, which by the action of cold water is partially transformed into an insoluble basic salt of the composition $CuSo_4 + Ca(OH)_2$. Another basic sulphate occurs native—brochantite, $CuSO_4 + 8\,Cu(OH)$—which is a mineral of a bright-green colour. (2) Certain basic phosphates are green insoluble bodies: thus, *libethenite* is a dark olive-green mineral, $CuPO_4 \cdot CuOH$; and *pseudo-malachite* $(CuOH)_3PO_4$, is emerald green. (3) The arsenates are green insoluble bodies—as the ortho-arsenate, $Cu_3(AsO_4)_2 \cdot 2H_2O$, a blue compound obtained by gently igniting together arsenate of lime and nitrate of copper. (4) The arsenites, as $CuHAsO_3$, which forms an important pigment known as Scheele's green, and under which heading we treat it. (5) Two *silicates* occur in nature as bright-green minerals: thus there are *dioptase* or *emerald copper*, CuH_2SiO_4, which is bright green, and *chrysocolla*, $CuH_2SiO_4 \cdot H_2O$, which is blue. (6) Several basic carbonates, as *malachite*, $CuCO_3 \cdot Cu(OH)_2$, are insoluble, which latter we treat as a pigment used in the arts. (7) Sulphides: the cuprous sulphide, Cu_2S, is black or grey, formed when copper and sulphur are ignited together, and also occurs native as copper-glance or *chalcocite.* The cupric sulphide, CuS, is a dark-brown compound formed by the action of sulphur or sulphuretted hydrogen, or an alkaline sulphide on a cupric salt. Therefore copper pigments, when subjected to sulphurous gases (as bad coal-gas), become more or less injured from the formation of copper sulphide, and this is one of their worst faults. The reader will thus understand the principles of the use of copper pigments, and will appreciate the better our remarks upon the fastness or stability of copper green compared with other greens. (8) Borate, (9) Stannate, (10) Zincate, (11) Acetate and Aceto-arsenite, are all insoluble compounds of copper, which are treated under their respective headings.

We now proceed to a short review of the methods of making and using such of the above-enumerated compounds as are found to be applicable for the purposes of the decorative arts.

Malachite Green,

Malachite, or mountain green, is a basic carbonate of copper, having the composition $CuCO_3 \cdot Cu(OH)_2$. It occurs native in many localities in Cumberland, and in the mountains of Kernhausen, as a beautiful green ore, and is simply ground to powder and washed, to render it fit for use. The ore is much used by jewellers. The shade of this natural pigment is brilliant, and varies from emerald green to grass green. It is not very fast against the action of light and damp air; sulphurous gases and alkaline liquids injure it, sulphur blackening it by the formation of the black sulphide. It is not injured by the prolonged action of *dry* air. Carbonate of copper may be prepared artificially by the cautious precipitation of bluestone with carbonate of soda, avoiding an excess of the latter; and careful washing and filtering render the precipitate fit for use as a pigment.

Malachite, or mountain green, is largely used in fine painting, but is inferior to Scheele's and other pigments.

Brunswick Green.

Genuine Brunswick green is an oxychloride of copper, of a bright but rather pale green colour. It is largely employed in house-painting, but not in fine-art work. When the ammonio-chloride of copper, NH_3CuCl, is treated with water, it forms a green precipitate, insoluble in water. Also, when an aqueous solution of cupric chloride, Cu_2Cl_6, is treated with a quantity of potash insufficient to decompose the whole of it, a pale-green precipitate is formed, which, on heating, is converted into a black powder; and on again treating with water yields a fine green powder, having the composition represented by the equation $2\,Cu_3ClO \cdot 3H_2O$. This is true "Brunswick green." It may be produced on the large scale by allowing hydrochloric acid to act slowly on poor copper ore with exposure to the air, the green oxychloride being gradually formed, together with a

proportion of the hydrated protochloride of copper, according to the equation

$$6\ Cu_2Cl + Aq + O_3 = 4\ CuCl + Aq + 2\ CuCl + 3\ Cu_2O.$$

It is collected, washed by careful decantation, after the ore unacted upon has been removed by mechanical means, and filtered.

Another largely employed method for making Brunswick green is to expose copper foil or clippings to the air, moistening it repeatedly with hydrochloric acid or sal-ammoniac, and then, when the copper has been sufficiently acted upon, treating with water.

Brunswick green occurs native in the form of the mineral *atacamite*, which, we believe, was formerly ground, washed, and employed as a pigment.

Brunswick green is but a moderately stable pigment. It is very susceptible to the action of heat; when gently warmed, water is gradually given off, and it assumes a dark colour; when more slowly heated it is completely decomposed, hydrochloric acid is given off, and it is converted into the black oxide of copper. It is insoluble in water; it stands exposure to the air for a long time. It is acted on by dilute acids and strong alkalies, which readily dissolve it.

It is used in house-painting, but never is employed in fine-art work.

Many of the "Brunswick greens" in the market are not in reality such, but are mixtures of Prussian blue and chrome-yellow, or vegetable lake yellow, the detection of which will be readily effected by the means we have before referred to or may hereafter describe.

Verditer or Bremen Green, or Green Bice.

This pigment is very similar in properties to Brunswick green, and does, in fact, consist largely of an oxychloride of copper, together with cupric hydrate and more or less of salts of the alkalies which form with this a double salt of copper and alkali. One method of manufacture consists in exposing scrape-copper to the air, as damp as possible, in large shallow vessels, together with *moist* common salt and sulphate of potash. In place of the latter salt some makers add a larger quantity of common salt, together with dilute sulphuric acid. When the copper is completely decomposed, it is mixed with about 7 per cent. of sulphate of copper (blue-stone) dissolved in water, and then 40 per cent. of a solution of caustic soda at 32° to 36° Bé. added. The precipitate is well washed by decantation, and filtered into a thick pulp, when, if necessary, a further quantity of water is expressed in a filter press, when it is ready for use as a green pigment. Careful preparation yields a useful green for house-painting, but it is inapplicable for fine-art work. As regards stability, it possesses the same objection as true Brunswick green, than which, indeed, it is commonly held in less regard.

Verdigris Green.

This well known and ancient pigment is a subacetate of copper, represented by the formula $(CuO)_2 \cdot C_4H_6O_3 \cdot 6\ H_2O$. As a pigment it does not possess many advantages over those last named, being equally sensitive to the action of foul gases and prolonged exposure to damp air. It is obtained by spreading copper clippings into a layer in a shallow vessel, and pouring over them a solution of acetate of copper, obtained by the action of vinegar on copper clippings or filings, and then covering with the skins of grapes undergoing acetous fermentation. Formerly much used, but now seldom; it has lost its reputation as a bright green, owing to its instability to light and moist air. It is not employed in fine painting.

Scheele's Green,

also known in commerce under the names of Swedish green, Vienna green, Kirchberger green, and Mitis green, is an arsenite of copper, obtained by mixing solutions of cuprous sulphate (blue-stone) and arsenite of potash, and washing the brilliant dark-green precipitate that forms. Owing to its highly poisonous nature, it is now seldom employed, as it possesses no material advantages over other equally cheap non-arsenical greens.

Under the names mineral green, Paul Veronese green, English green, Neuwied green, there occur in the market pigments which, on analysis, turn out to be nothing else than mixtures of Scheele's green with sulphate of lime.

Schweinfurt or Emerald Green—also known in the market under the names of Mitis green and Imperial green, and, as if to confuse artists as much as possible, often designated Vienna green and Brunswick green—is an aceto-arsenite of copper. It is most conveniently prepared in the following manner:—1 lb. white arsenic (As_2O_3) is boiled in a solution of $22\frac{1}{2}$ oz. pearlash in 1 gallon of water until dissolved. This is then gradually mixed with a hot solution of 1 lb. of sulphate of copper in as little water as required to dissolve it. The mixture is well stirred, and kept near the boiling temperature for some time, and is then filtered, and acetic acid added until it assumes a bright-green colour; a slight excess of acetic acid is then added, and the mixture is boiled, washed by decantation and filtered, and is ready for use.

Having now described the common and well-known copper greens, it remains for us to glance at other green compounds of copper which have been proposed as pigments, but which possess no material advantages over those already given.

Copper Borate is a compound of a yellow-green colour of moderate permanence. It is prepared by precipitating sulphate of copper with borax, washing, drying and carefully igniting, levigating, drying and grinding for use. It is deficient in body.

THE BUILDING AND THE MACHINE DRAUGHTSMAN.

CHAPTER XXII.

PROCEEDING with our description of the methods of obtaining the positions of "lines of heights" on the plan of the building to be put into perspective, as in fig. 1, Plate VIII., we have to state that similarly for the side elevation, one line of heights will be required for the elevation on the line C D, and another for the recessed portion. Prolong the line B C until it intersects the line H H: the point of intersection will give the position of the line of heights for the elevation on the line B C; by prolonging the lines N N, D C, until they intersect the line H H, the positions of the respective height lines will be obtained. In fig. 2, Plate VIII., the positions of the lines of heights are obtained by prolonging the lines B C, J′ J, C D, D E, until they intersect the line H H.

When the architect or student is drawing the plates shown in figs. 1 and 2, Plate VIII., to a larger scale, or the plan and the diagram of the "station point," "vanishing points," and the positions of the lines of heights of any building or object of which a perspective is to be prepared, the following points should be attended to, so as to avoid inconvenience and loss of time. The distance between the vanishing points should not be greater than the length of the drawing board on which the drawing is "pinned"; should the distance be so great that no drawing board is available, then the drawing should be pinned or better still damped and gummed round its edges to a drawing desk, and the positions of the distant vanishing points marked, so that they can always be found when wanted; a long baywood bevelled straight-edge cut to the required length must also be provided. The explanation of the technical terms given above has been confined to the plan; we must now direct the reader's attention to the perspective proper, or rather in the first instance to the sheet of paper on which it is to be drawn, which may be represented by A B C D, figs. 3 and 4, and thus represents the "picture planes" or line H H, figs. 1 and 2, Plate VIII. Two lines must in the first instance be drawn, extending from right to left and parallel to each other: the "horizontal line" and the "ground line." First draw the "ground line" E F in such a position that the perspective will occupy the centre of the sheet with equal margins above and below. The centre line, G G, of the sheet should then be faintly drawn; mark off on the line G G the height of the "horizontal line" above the "ground line" to the same scale to which the plan, figs. 1 and 2, are drawn. Presuming that the perspective is intended to represent the appearance which the building will have to an individual standing at the point G, figs. 1 and 2, Plate VIII., then the height of the horizontal line above the ground line will be, say, 15 ft. 6 in.; if the view were taken from an elevated position, as for instance the window or roof of a neighbouring building, then the height to be scaled off would be 20, 30, or 40 ft., as the case might be. Suppose the required height has been marked off at the point X, then draw the line H H through the point X parallel to the line E F; H H will be the "horizontal line." The various points on the line H H, fig. 1, Plate VIII., must now be transferred to the line H H, fig. 3, Plate VIII. First take the line J J from fig. 1, which represents the length of the intended perspective, and mark it off on the horizontal line, so that the centre line G G bisects it; let the points J‴ J‴ represent the length of the proposed perspective. Next carefully measure off all the various vanishing points and lines of height on the picture plane H H, fig. 1, and transfer them to the horizontal line on fig. 3. This is easily and accurately done by means of a long strip of paper; in order to avoid confusion, mark each point respectively, V P vanishing point, and H L height line. Through the points marked H, L, draw lines at right angles to the "horizontal lines,"—these are the "lines of height."

On fig. 3 the height lines and vanishing points shown on fig. 1 are drawn, and on fig. 4 the height lines and vanishing points shown on fig. 2.

The general arrangement of these diagrams must be applied to every perspective, whether an exterior, an interior, or a bird's-eye view,—and equally so if the perspective is to represent the simplest and smallest cottage, or the largest mansion or cathedral; it is absolutely necessary, therefore, that these introductory remarks should be thoroughly understood before the reader proceeds to the next portion of the paper.

In figs. 1 and 2, Plate VIII., the plans have been drawn parallel to the sides of the plate, the lines of the picture plane diagonally across it, and the plan diagrams and elevation diagrams have been kept separate; in practical perspective it is generally found simpler to reverse this arrangement of the plans, and to draw the diagram of the elevation below that of the plan, if a sheet of drawing paper of suitable size can be obtained. This arrangement is shown on Plate XV., which simply consists of the diagrams shown on Plate VIII. arranged as they would be by the practical perspective draughtsman.

Having in the preceding chapter detailed the general principles of applied perspective, we shall now proceed with a practical example of perspective, and explain step by step the process of preparing a perspective view of the villa illustrated on Plate LXX. by front and side elevations and ground and first floor plans. The two principal elevations are, of

course, those containing the windows of the entertaining rooms and the main entrance; a point of sight, A, must therefore be selected from which they can both be seen. A diagram, Plate XLVII., must then be prepared on a suitable sheet of drawing paper, carefully pinned on a substantial drawing board, similar to the diagrams shown on Plate XV. Commence by placing the point of sight, A, on the paper, and firmly fix an ordinary pin in an upright position at the point. Through the point of sight draw a vertical line, A D, with a T-square from the top to the bottom of the drawing paper; two lines, A B, A C, must then be drawn, meeting at the point of sight, enclosing an angle of sixty degrees, which must be bisected by the vertical line just drawn. These lines, A B, A C, will enclose the extreme points of the plan of the villa. The line of the picture plane must be drawn at right angles to the vertical line A D, in the position shown on Plate XLVII., in order that the perspective may be equal to the length E E, the points at which the picture plane crosses the lines A B, A C. The next step is to place the ground plan in the position shown on the plate, so that its extreme points will fall within the lines A B, A C. This is easily done by having an outline of the plan drawn on a small, separate sheet of tracing paper, which can be moved about until the desired position is obtained, when it must be firmly pinned down. The position selected is one (as already stated) that presents the entrance elevation and what may be appropriately called the garden elevation to the point of sight A, and rather more of the entrance front than of the other. The point of sight A is placed as far from the nearest point of the plan as the size of the plate will allow; a distance equal to the length of the two elevations would give a better perspective. The reader will of course know, from what has been already stated, that only two vanishing points are necessary in this instance; their position on the plan, Plate XLVII., is obtained by drawing the lines A F, A G, from the point of sight A, parallel to the sides of the outline plan intersecting the line of the picture plane at the points F and G. Similarly the position of the lines of heights on the plan diagram, Plate XLVII., are obtained in accordance with the rule given above by prolonging the several frontages of the plan until they intersect the line of the picture plane. A short study of the front and garden elevations and of the plans on Plate LXX. will no doubt enable the reader to decide for himself how many height lines are required. For the front elevation one will be necessary for the gable on the left-hand side of the tower containing the drawing-room and bedroom No. 2 windows; this line of frontage is therefore prolonged until it intersects the picture plane at H L.

A second height line for the front of the tower and of the dining-room gable, which are in the same plane, and another for the centre of the tower roof, will be required. The garden elevation will require height lines for the main wall, the front of the bay windows, the slight projections on the first floor, and the ridge of the main roof; these lines are therefore prolonged as well, as shown on the outline plane, until they intersect the picture plane. In order that the height lines may be readily distinguished they are drawn thus —.—.—.—, and the lines associated with the vanishing points thus — — — —, on Plate XLVII. The preliminary work of the plan diagram is now complete. Near the bottom of the same sheet of drawing paper draw the ground line (Plate XLVII.), and five feet six inches above it the horizontal line, using, of course, the same scale as that to which the plans and elevations on Plate LXX. are drawn. Fix the positions of the vanishing points on the horizontal line by drawing the vertical lines F V, G V, from the points F and G on the picture plane down to and intersecting the horizontal line. It is usual and convenient to fix ordinary pins into the drawing board at the points V, V′, and A, and to keep them in position until the perspective drawing is completed, to facilitate the drawing of all lines converging to those points. Draw the vertical height lines H^1, H^2, H^3, H^4 and H^5 from the intersections on the picture plane to the ground line; these are the height lines. Everything is now ready for the commencement of the perspective. The main vertical lines of the elevation must be drawn first—namely, the corners M, M^1, M^2, Plate XLVII.; draw lines from these points to the point of sight A, and from the points at which they intersect the picture plane draw vertical lines to the ground line below. Draw similar lines from the projecting corners of the tower, and from the points N N to A, intersecting the picture plane, and vertical lines to the ground line from these intersections. All the main vertical lines of the elevation have thus been drawn. The main horizontal lines must be put into perspective next, including the ground line, the plinth, the ground and first floor window sills, the string course, and parapet. Mark off from the elevation all these heights on the height lines, measuring from the ground line upwards. Commence with the portion of the front elevation on the left-hand side of the tower; from the various heights marked off on the height line H^2 draw lines towards the vanishing point V^1; the horizontal lines of the front of the tower and of the gable on the right-hand side of the tower must be drawn in the same way, but of course from the height line H^3. A portion of the elevations of the tower and of the gable on the right-hand side of it, parallel to the garden elevation, will appear in the perspective P and P^1, Plate XLVII. Special height lines will not be required for them in this case, as the horizontal lines

can be drawn from the vanishing point V so as to mitre with those already drawn.

All the main vertical and horizontal lines of the front elevation have now been put into perspective, The garden elevation must be taken next. The vertical lines of the bay windows will be required. Connect the points R, R, R′, R′, to A by straight lines, and from the points where they intersect the picture plane draw vertical lines to the ground line; the heights for the front of the bay windows must be marked off on the height line H^4, and the horizontal lines drawn from this height line to the vanishing point V. From the corners R′, R′, of the bay windows draw horizontal lines to the vanishing point V′ for the return ends, mitring with those already drawn. The student will now perceive that in every case in which horizontal lines of two adjacent elevations mitre with each other one height line can be dispensed with: thus no height line will be required for the elevation of R M, Plate XLVII. As all the horizontal lines mitre with those of the front elevation, and as they have already been drawn, it is only necessary to connect them where they intersect the line K K with the vanishing point V. To put the gables into perspective the centre lines are required; mark their position on the outline plan. Plate XLVII., at S, S, S, S; draw straight lines, as before, from S, S, S, S, to the point A, and from the intersections on the picture plane draw the vertical lines to the ground line; mark off the height of the apex of each gable on the respective height line; for the gables of the front elevation connect the points on the height lines with vanishing point V′ by straight lines, and the points at which they intersect the centre lines just drawn will be the apex of each gable; for the gables of the garden elevation use the other vanishing point. Repeat this operation for the bottom or foot of the gables, and then connect the bottom with apex. The main outline of the perspective is now completed, consisting of all the longer vertical and horizontal lines and the gables. In order to put the roof into perspective the roof ridges must be drawn on the outline plan, as shown on Plate XLVII., and must be prolonged so as to intersect the picture plane in order to obtain the position of the height lines; draw the vertical height lines, and mark off the heights of the respective ridges; draw those parallel to the garden elevation down to the vanishing point V, and those parallel with the front elevation to the vanishing point V′. The roof over the tower is put into perspective in the same manner; draw the hips on the plan as shown at T, Plate XLVII. Join the apex with the point of sight A by a straight line; at the point at which it intersects the picture plane draw a vertical line to the ground line,—a height line will of course be required; from the apex R draw a line parallel to either of the two elevations, for instance to the front elevation, as shown, until it intersects the picture plane; from the point of intersection draw the height line H′, mark off on it the height of the apex of the tower roof; join to the point with the vanishing point V′ by a straight line, and the point at which it intersects the centre line of the tower roof just drawn will be its apex Z. If the height line for the tower roof had been drawn on the plan parallel with the garden elevation, instead of the front elevation, then the vanishing point V would have had to be used instead of the vanishing point V′.

If the reader has, in addition to following the above description on the plates referred to, also prepared a drawing—which should, of course, be to a scale of eight or four feet to an inch—he will now have completed all the main portions of his perspective, and will be ready to proceed to the minor architectural features—namely, the window openings, heads, quoins, front door, steps, and chimneys. The principle of drawing these details in perspective does not in any way vary from that used for the other portions of the elevations; in each case the same simple rules must be repeated, and when these are thoroughly understood the process of preparing a perspective becomes merely a question of perseverance and patience.

In the above description of preparing a perspective drawing it has been stated that the various points on the plan (Plate XLVII.) must be connected with the point of sight A by a straight line, in order to obtain the intersection on the picture plane. In practice it is not necessary to draw the line; the two points (the one on the plan, for instance, M—M^1 or M^2, and the point of sight A), are carefully joined by a set square or straight-edge, and merely a "tick" made where the imaginary line intersects the picture plane. In the same way it is not necessary to draw long vertical lines from the picture plane to the ground line,—merely a line of approximately the length required; by placing the set-square carefully against the "tick" on the picture plane, this can easily be done. The lines converging to the vanishing point should also only be drawn of the length absolutely required. If these directions were not adhered to, the drawing would soon become a mere confused mass of lines, which would cause endless trouble and loss of time.

Proceeding now to the details of the perspective on Plate XLVII., we commence with the windows. There are three tiers: the ground floor, first floor, and those in the gables and in the tower; they consist of the actual openings, the mullions, stone quoins and window heads, which must all be drawn on the outline plan, as on the Plate.

THE IRON MAKER.

The Details of his Work and the Principles of its Processes.

CHAPTER XI.

At the end of last chapter we opened up the subject of the practical management of the blast furnace, by showing the importance of having the furnace quite dry before beginning to fire it up. To insure this in the Cleveland district, which we selected as an example, huge masses of firewood are deposited in the furnace, to the weight of a ton or a ton and a half. Then about five or six tons of coke is laid on the top of the wood. Upon the layer of coke is now laid a sufficient charge of coal, coke, flux, and a small proportion of ore, filling the furnace up to about one-third of its height, after which the firewood at the bottom is fired. As the flame ascends to the top layer of materials, additional supplies of fuel, ore and flux are thrown in—at first slowly, and then in increasing quantity. In this, however, some care is necessary; as, if a fresh supply of fuel is added before the previous supply is burned red, there is a tendency to an accumulation of inflammable gases,—this, indeed, sometimes happens to such an extent as to occasion an explosion. As the fuel is consumed, the resulting ashes and refuse are removed at the fore-part of the "stack." The water tubes connected with the tuyères are provided with the requisite water, and the tuyères properly adjusted. A light blast is now driven into the furnace, and more materials are added. The accumulated ashes are removed, stoppings placed in the tapping hole and beneath the tymp, the bars and brickwork removed, the dam-stone bedded. So soon as the cinder falls upon the hearth the blast is increased, and so is the burden of fuel, flux, and ore. The cinder flows in a fluid state to the bottom of the furnace; the melted iron falls to the hearth; the cinder ascends, flows through the "cinder notch" in the dam-stone down the "fald." At first it will be noticed that the resulting cinder is coloured green or brownish, but as the process is continued the cinder is of a light blue colour. Several hours afterwards the furnace is slightly tapped; but even in small furnaces the blowing-in takes a few days, until the furnace is filled completely, and after this has been attained full charge and blast may without danger be admitted. It is not unusual to add a quantity of blast-furnace cinder just when the "stack" is filled with hot fuel to about half its height, and continue adding a small proportion with the other materials until the stack is two-thirds full. The object of this is so to heat the surfaces of the "hearth" before the metal is melted as that the fluid iron shall not come in contact with the cold hearth, and so stick, occasioning some annoyance. At the fore-part there is an iron grating situated about two feet above the bottom of the hearth. This arrangement is for the removal of ashes. When a sufficient quantity of melted iron has collected—*i.e.* when the surface of the metal has become too great to be completely covered by the siliceous coating of impurities, and so tends to overflow, the cinder overflowing into the cinder notch—the tapping hole is unstopped and the metal run into casts on the floor of the casting house formed in sand. The mould or cast into which the metal flows consists of one large principal channel from which minor side-branches radiate. The main runner is designated the "sow," while the smaller channels are the "pigs." When the metal is withdrawn, it is accompanied by a small quantity of cinder, to get rid of which the blast is continued until the "keeper" or furnaceman removes all ashes and renews the tymp and tapping stoppings. The blast and entire action of the furnace now goes on, and repeats what we have seen to be its operations. An important point to be attended to, before the blast engine is stopped for the operation of moulding, is to remove, and not replace until after the casting is over and the blast set in motion, the sight-hole stoppers in the tuyères. Should this precaution not be taken, there is great danger of a destructive explosion. This would arise from the gas entering the blast pipes from the stack, unless air were admitted at the plug-holes in the tuyères. When the tuyère sight-holes are re-stopped, the nozzles should be looked to, to see that they are not in any way clogged, thus preventing the free entrance of the blast. Another point to be attended to is to see, in the technical language of the trade, that the "tweers are bright"—that is, the fuel burning vividly.

The Structures and Appliances used in the Manufacture of Pig-Cast-Iron.—The "Plant" of the Trade.

As already incidentally referred to, the blast furnace, although of comparatively large diameter, is characterised chiefly by its height. Formerly this height was relatively low—furnaces of forty and sixty feet in height being the rule. But the tendency of modern iron making has for long been in the direction of increasing the height, and with the height the diameter, until a cubical capacity has been reached far beyond what the old iron masters ever dreamed of. The gradual increase of cubical capacity may be learned from a statement of a well-known works—at which the furnaces erected about thirty years ago had a capacity of 5,079 cubic feet, those erected twenty years ago a capacity more than threefold, or 16,000 cubic feet, those erected twelve years ago a sixfold capacity, or 30,000 cubic feet. And although this may be taken as the general limit of increase, furnaces of even greater capacity than this have been since erected. From a height of forty to sixty feet, furnaces are now common, especially in the Cleveland

district, of a height of seventy, and in some cases exceeding even a hundred feet. Taking, however, a height of seventy feet as common enough now-a-days, even in districts other than the Cleveland, the reader will perceive that to raise the materials of the charge to this altitude may in some instances of locality involve appliances more or less complicated and costly.

This position, and such considerations as flow from it, we shall illustrate in the few following sentences, and by aid of simple diagrams. In order to a due understanding of what is thus to follow, let us glance at the general arrangements of the buildings and appliances of a first-class blast furnace or iron works. From what we have above said, the reader will understand that the arrangements of the various structures and the character or nature of these, as well as of the mechanical appliances by which their work is aided, will vary not only according to the circumstances of locality, but according to the views entertained by the iron master and his engineer as to the kind of plant best calculated for the peculiar circumstances of the case. In view of this, while endeavouring to convey to the reader a fair conception of the general characteristics of "iron works," we have to give what may be called representative plans or views, the different parts of which constituting the whole as given, may not all be met with in any one particular works; and in which, although the character of the work to be done at the various structures is the same in all classes of iron works, the appliances by which that work is done may, and do in practice, vary according to circumstances, and the views entertained by the engineers in respect of the utility and economy in working of different forms of mechanism. But as the greater includes the less, we select for illustration a first-class iron works, in which are found all the structures and appliances necessary to work them.

The General Arrangement of the Furnaces, etc., etc., of Large Iron Works.

The general position of the various structures and appliances will be understood by an examination of fig. 2, Plate CLXVII. In this, which is a diagrammatic plan of the iron works, *a, a, a, a*, represent the calcining kilns or stoves in which the ironstone (ore) and the limestone (flux) are calcined or burnt. This operation is not, as we have elsewhere explained, always carried out; it may be applied to both materials, or only to one of them, as for example the ore,—or both iron ore and flux may be used in the raw or natural condition. For the purpose we have in view, however, we assume that calcining is carried out. The calcining stoves or kilns being "fed" or supplied with their materials at their upper part, and their height being considerable—say some thirty-five feet or so—the materials to be calcined must be lifted up to the "feed" level. In some localities the level of the place at which the materials are delivered to the works is so favourably selected that the trucks containing them can be run on by the force of gravity down a gentle incline, or pushed or dragged on with comparatively little expenditure of force. We here assume, however, that the site of the iron-works is throughout on a level or nearly so with that of the surrounding locality or neighbourhood,—in which case, therefore, the structures raised on the site for the purposes of the iron works will, while they vary in height, be all at a considerable elevation above the ground level or general surface of the site. This, therefore, necessitates mechanical arrangements by which the materials to be calcined are lifted up from the general level of site, which in fig. 1, Plate CLVI.—which is a diagrammatic elevation—we assume to be the line 1 2, up to that of the feeding mouths of the calcining kilns or stoves. This lifting is performed by means of a "hoist"—the position of which is shown at *b* in fig. 2, Plate CLXVII. and fig. 1, Plate CLVI., the amount of "lift" of the hoist being, say forty feet. This lift raises the materials to the level of "rails" which run along, and are supported by the timbers of a scaffolding technically termed a "gantry," marked *c c* in fig. 2, Plate CLXVII. and fig. 1, Plate CLVI. This gantry commands the whole range of calcining kilns or stoves, *a, a, a, a*—the trucks, one of which is shown at 3 in fig. 1, Plate CLVI., running along the gantry. Those trucks weigh some 14 to 17 tons, and are lifted bodily up in an appropriate stage by the hoist from the ground level 1 2, fig. 1, Plate CLVI., to that of the gantry at *c c c*. Each truck is provided with a bottom which can be opened and closed at will by the workman; and as each one is lifted up by the hoist and descends by the force of gravity from the lifting cage of the hoist on to the rails of the gantry *c c c*, it is dragged or pushed forward till it is placed over the feed mouth of the calcining stove, when, the bottom being opened, its contents are delivered. On being emptied of its load, the truck is taken forward to the end of the gantry *c c*, opposite to that (*b* in fig. 2, Plate CLXVII. and fig. 1, Plate CLVI.) at which it was delivered; and at this point arrives at what is called the "drop," marked in position at *d d*. This "drop" is, like the "hoist" *b*, provided with a "cage." The empty truck moves on to this, and by means of the mechanism of the "drop" the cage is lowered to the ground level, fig. 1, Plate CLVI., and passed on to the rails, and by a "siding" taken out of the "works." A constant succession of full and empty trucks is thus dealt with as materials arrive on the ground for use—the full trucks being lifted by the hoist *b*, the contents delivered to the calcining stoves *a, a*, passed along the gantry *c c* to the "drop" *d*, and by it delivered again to the original level. Calcining

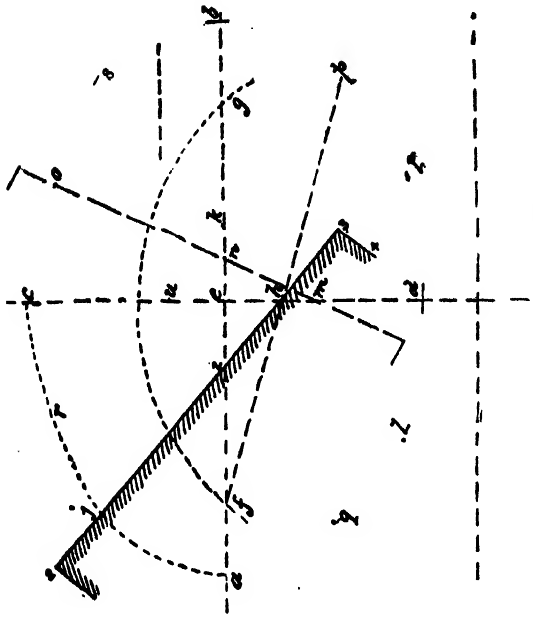


Fig. 3.

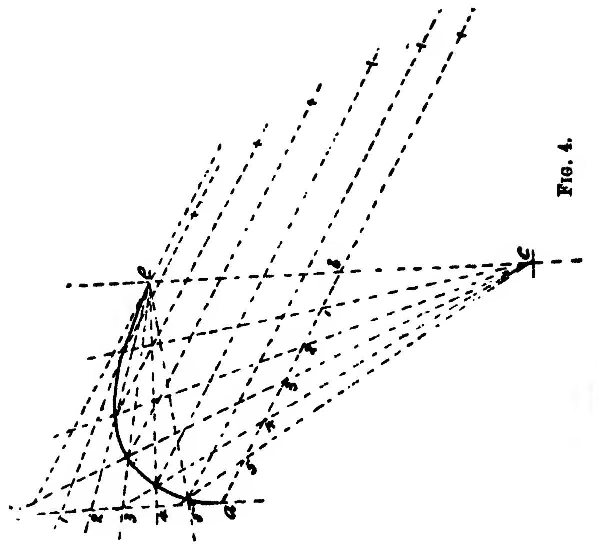


Fig. 4.

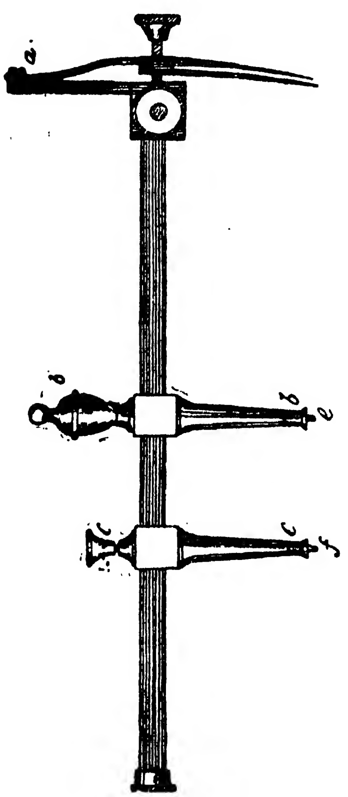


Fig. 1.

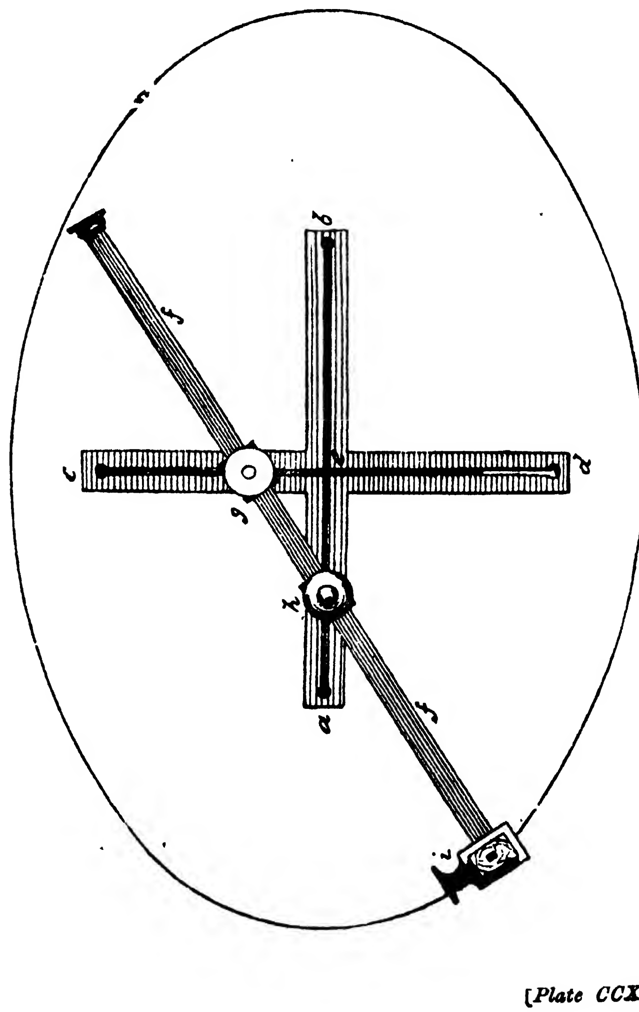


Fig. 2.

THE GARDEN AND FARM ARCHITECT.—STABLES, DAIRIES, ETC.

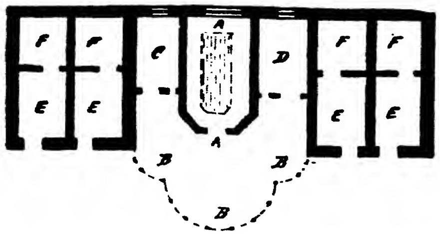


FIG. 1.

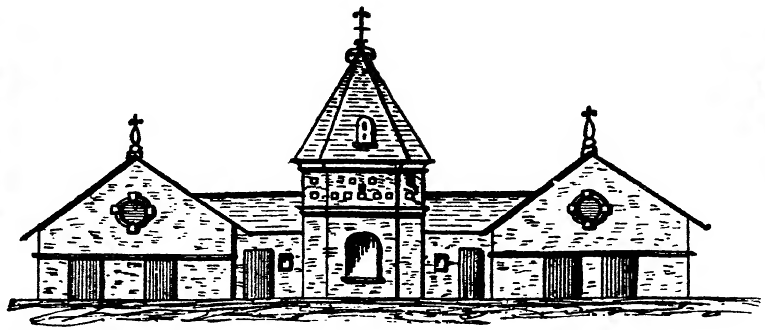


FIG. 2.

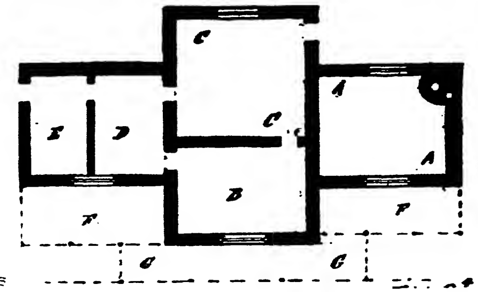


FIG. 3.

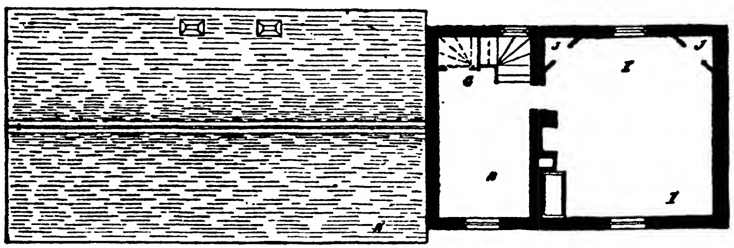


FIG. 4.

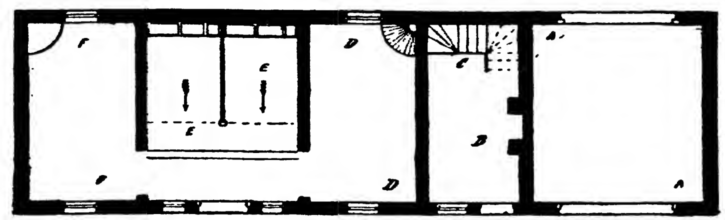


FIG. 5.

FIG. 6.

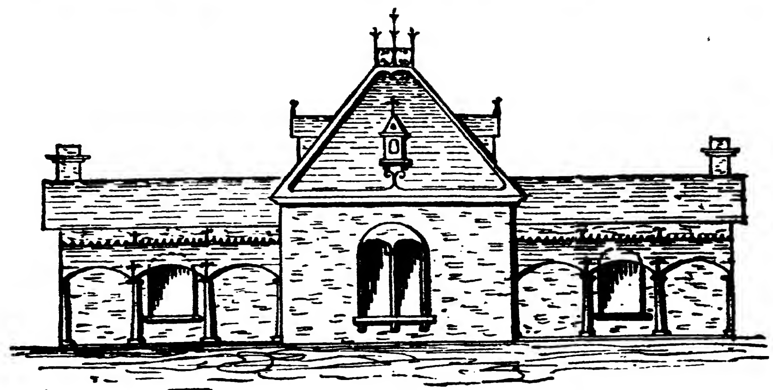


FIG. 7.

FIG. 1, NORMAN; FIG. 2, SEMI-NORMAN; FIG. 3, NORMAN; FIG. 4, EARLY ENGLISH; FIGS. 5, 6, 7, DOMESTIC GOTHIC.

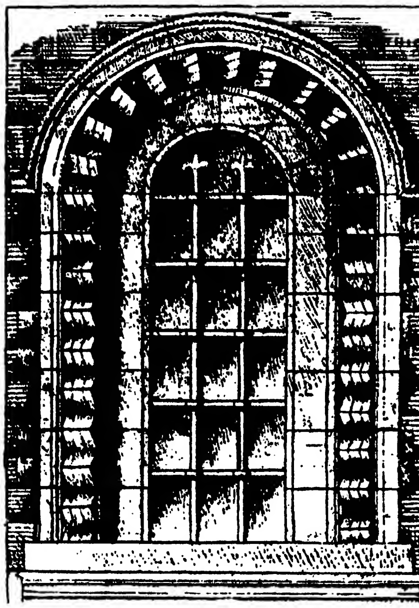


FIG. 1.

FIG. 2.

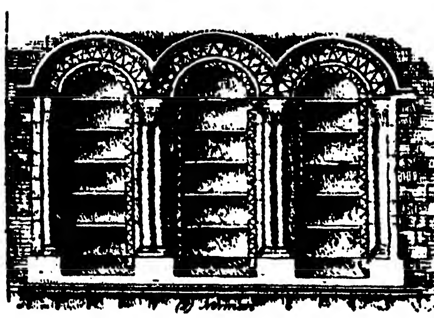


FIG. 3.

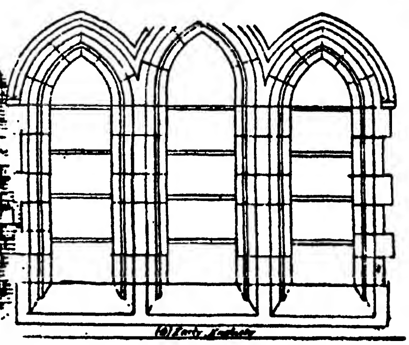
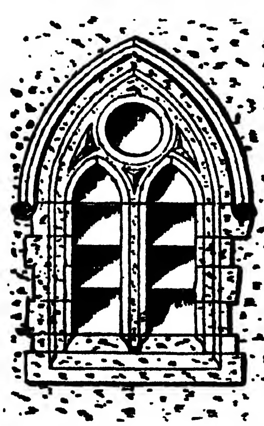
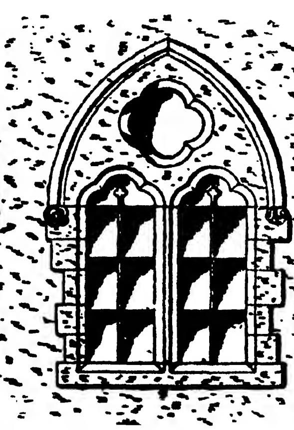
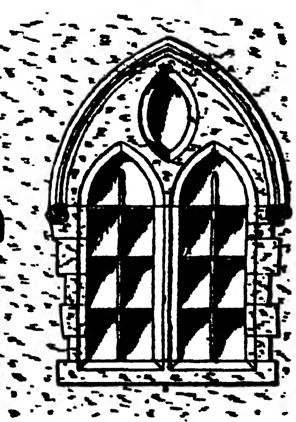


FIG. 4.







GOTHIC WINDOWS

FIG. 5. FIG. 6. FIG. 7.

FIG.1

FIG.2.

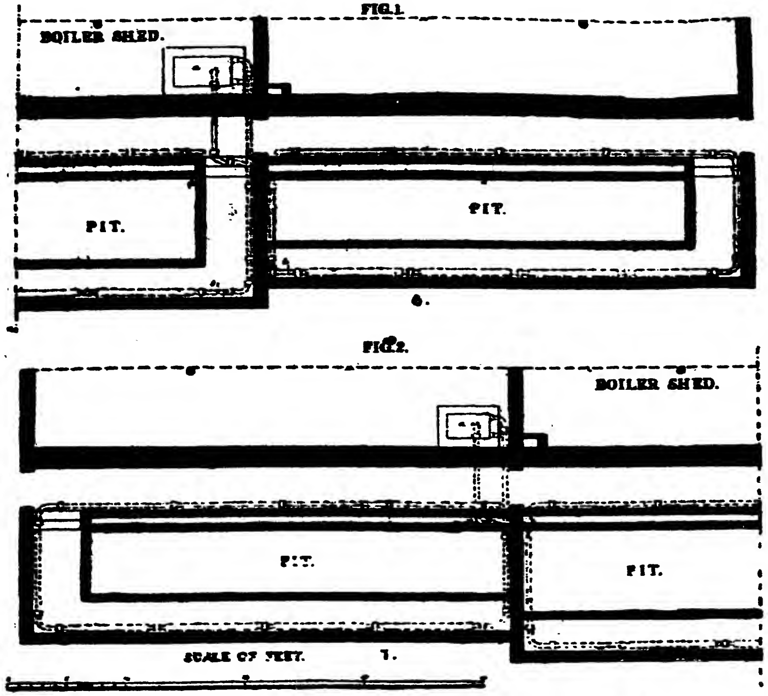


FIG.3.

PLAN OF FORCING HOUSES.

SHEWING ARRANGEMENT OF HEATING-PIPES.

REFERENCE.

FIG.1. Half Ground Plan (right hand)

FIG.2. Half do. do. (left hand)

a a boilers. b b stoprocks.

FIG.3. Transverse Section.

GROUP No 1.

Fig. 1.

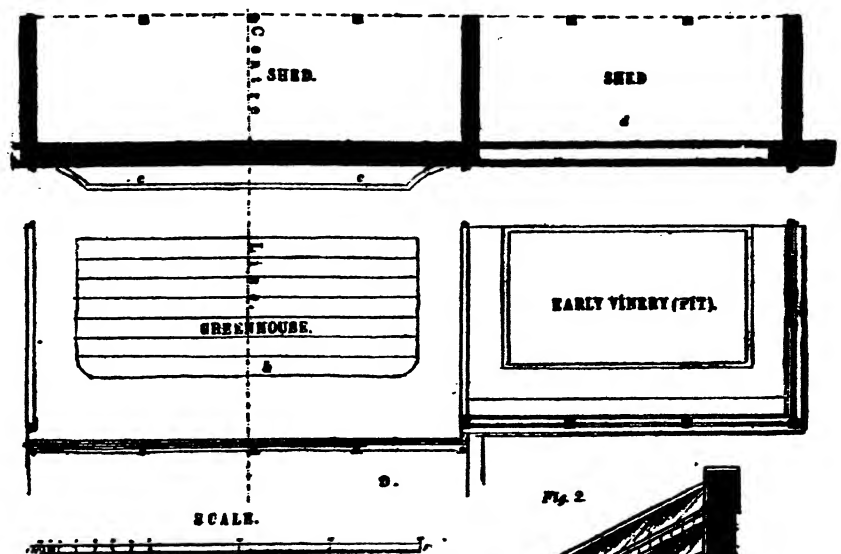
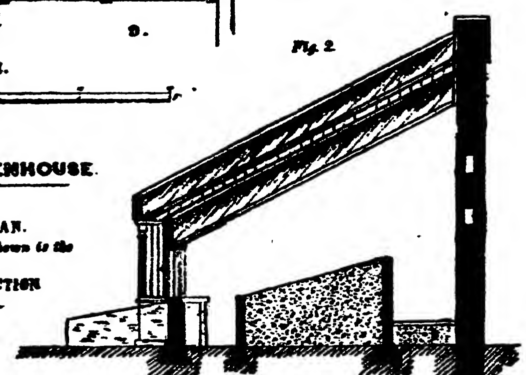


Fig. 2



VINERIES AND GREENHOUSE.

(FIG.1. PART GROUND PLAN.
The Vinery Pit not shown in the last one.
FIG.2. TRANSVERSE SECTION

GROUP No. 2.

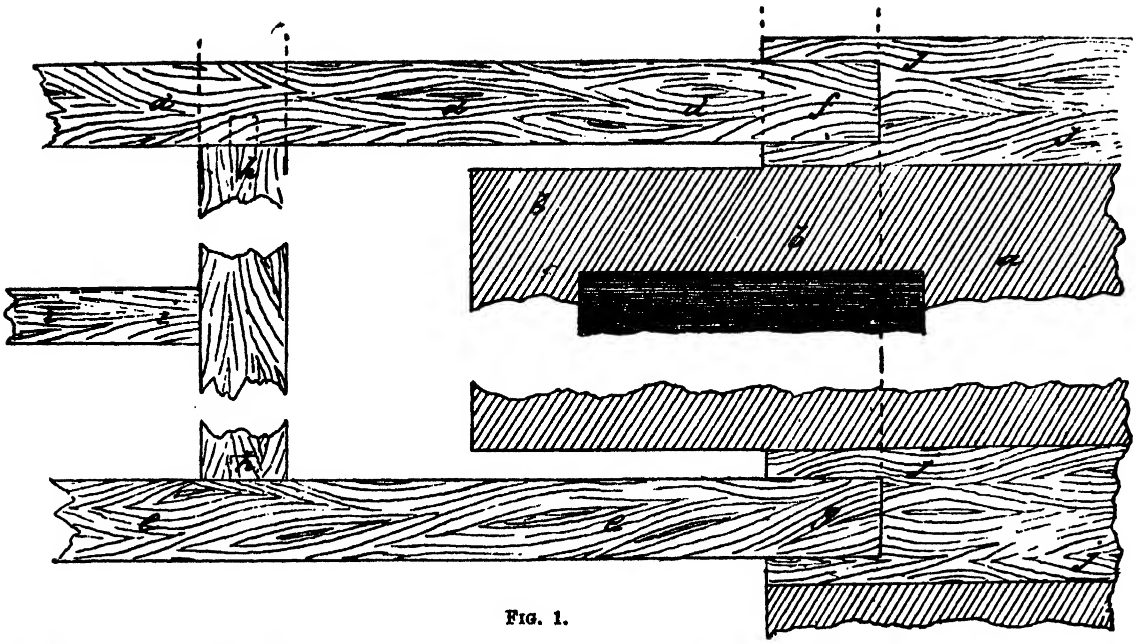


FIG. 1.

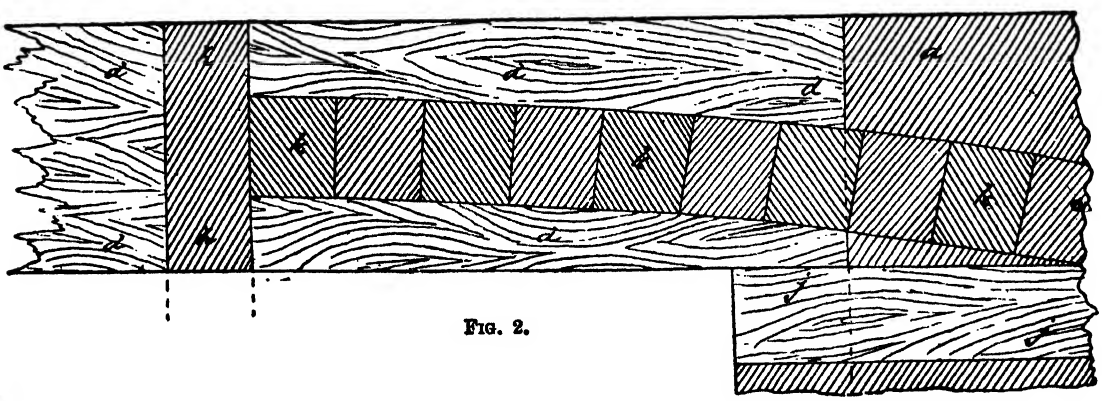


FIG. 2.

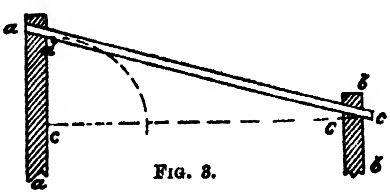


FIG. 3.

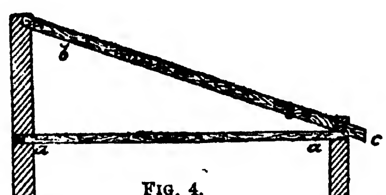


FIG. 4.

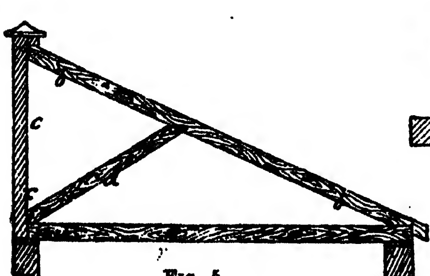


FIG. 5.

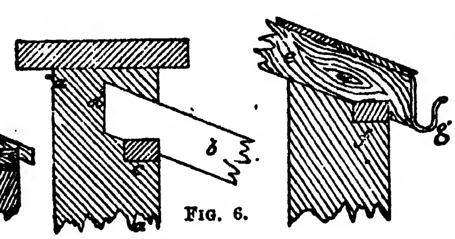


FIG. 6.

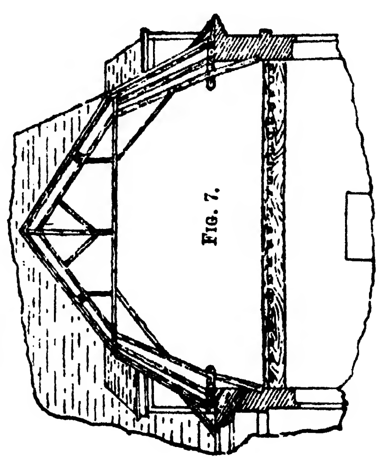
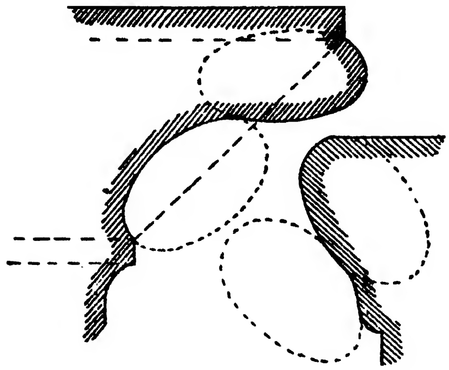


FIG. 7.



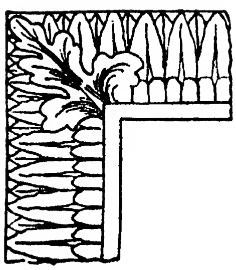


FIG. 2.

FIG. 3.

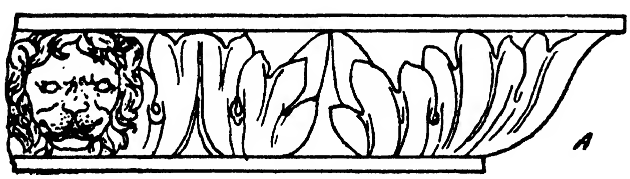


FIG. 4.

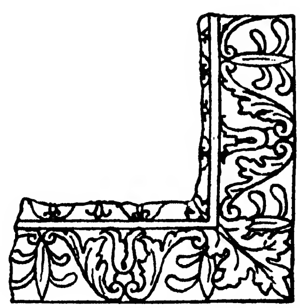


FIG. 5.

FIG. 6.

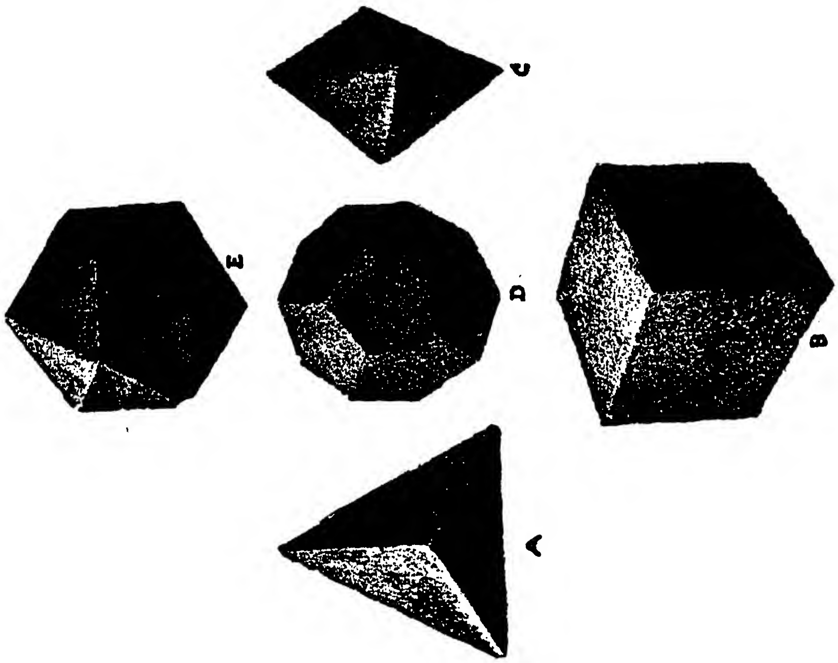


FIG. 2.

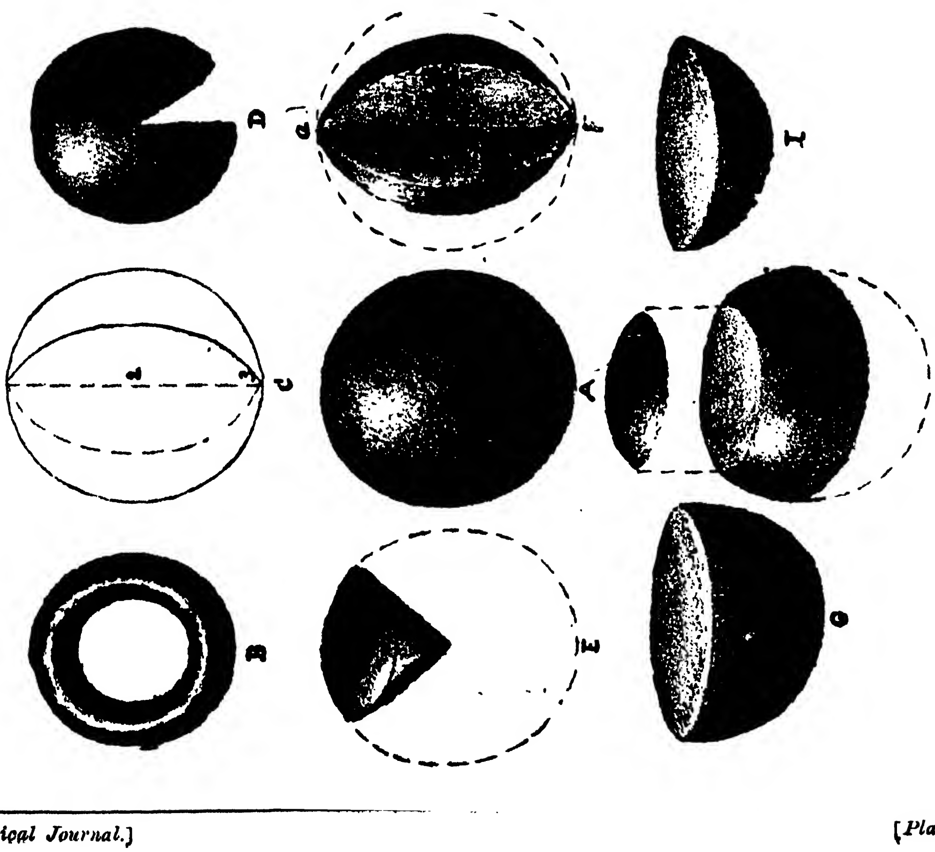


FIG. 1.

Development of Surfaces.

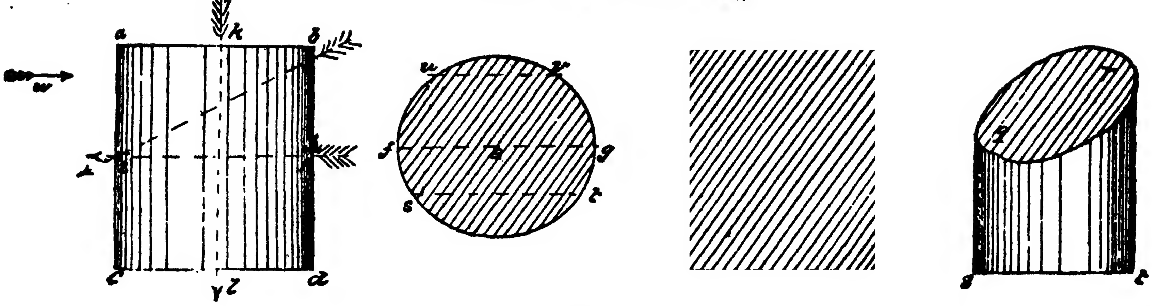


Fig. 1.

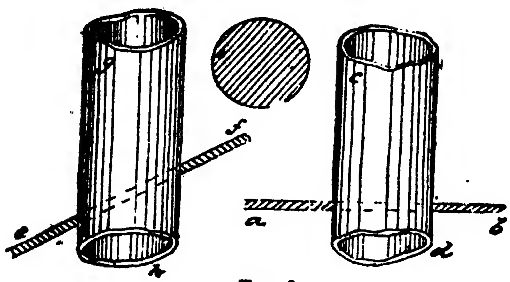


Fig. 2.

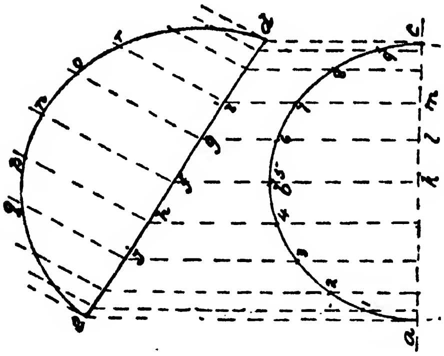


Fig. 3.

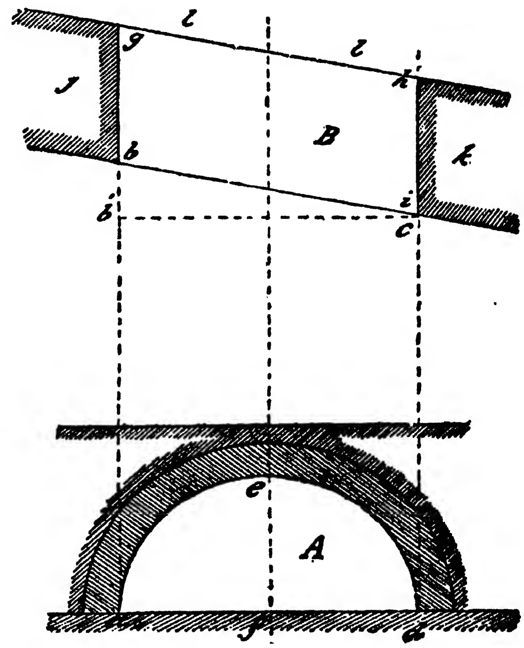


Fig. 4.

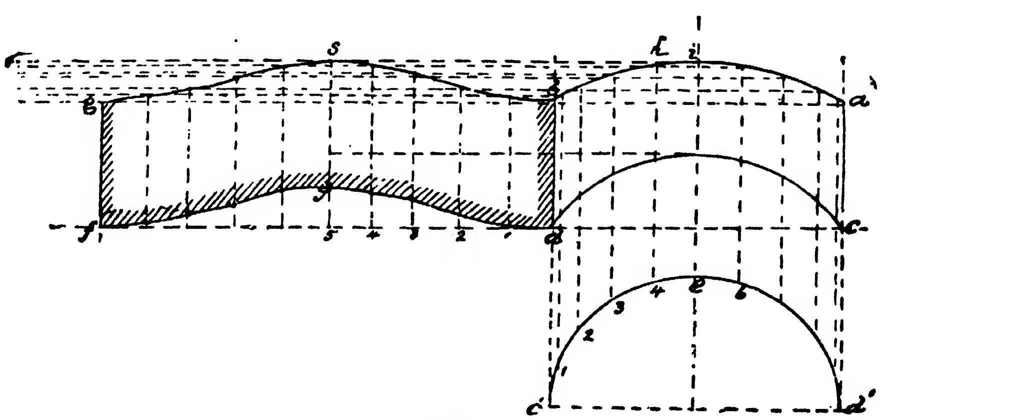


Fig. 5.

may be confined only to the ore or ironstone, or it may be carried out in both the ore and the flux (limestone). And in this latter case a separate calcining stove is allotted to each material—one stove being used to calcine the ore, the other the limestone. The ore and the limestone may be both calcined in one stove, the materials being tipped in as they are brought up to it. In all cases small coal is mixed with the material or materials to be calcined, this being brought forward also in trucks hoisted by the lift or hoist *b*, and taken down to the working level by the "drop" *d*. But in well arranged works, in order to avoid the contingency of loss of time arising from a short supply of coal used for calcining —*i.e.*, to promote and keep up the necessary combustion—a supply is kept in a "bunker" placed near the hoist or lift *b*. The delivery shoot of this coal "bunker" is placed so high above the rails of the gantry *c c* that a truck can be passed underneath, and this, when filled with the coal from the beaker, is passed into the calcining stoves as desired. The coke used in the blast furnaces, forming even for a single day's supply a large bulk of material, if this were allowed to lie loosely on the ground level ready to be supplied to the blast furnaces, would form an element of considerable disorder in the works. To avoid this, and to facilitate by due order the economical working of the blast furnaces, huge bunkers capable of holding some two hundred and fifty tons of coke are erected in connection with the gantry *c c c*. These are supplied by trucks, which also, like those containing the materials for the calcining stoves, are lifted from the general or ground level of the works by means of the hoist *b*, figs. 2, Plate CLXVII. and 1, Plate CLVI., to the level of the gantry, and taken to the delivery mouth of the bunkers and tipped in.

Working Plant of the Cast Iron Manufacture.—Delivery of the Charge in the Blast Furnaces.

We now come to the points connected with the delivery of materials or the "charge" of the blast furnaces. First as to the ironstone or ore, which in our case we presume has been calcined in the kilns or stoves *a*, *a*, fig. 1, Plate CLVI. Those kilns are cylindrical at the upper part, as shown in the diagram, some twenty-six feet in diameter, and have a capacity of nearly sixteen thousand cubic feet. The lower part is in the form of an inverted cone, this shape allowing the calcined materials to descend gradually, and to be easily removed. This lower part is provided with openings all round its lower extremity, through which the calcined materials are withdrawn—if those be a mixture, as at some iron works, of ore and flux, or simply, as at other works, of ore only. The calcined ore is placed in barrows, and these are wheeled at once to the "cage" or lifting stage of the blast furnace hoist or lift. The position of this in relation to the pair of blast furnaces which it equally supplies with materials is shown in the general plan in fig. 2, Plate CLXVII., at *i i*, being placed centrally between the two blast furnaces *h h*. The arrangement in elevation is shown in fig. 3, Plate CLXVII., correspondingly lettered. The height of the platform at the working mouths or throats of the furnaces from the level of the ground varies, of course, with the height of the furnaces. Those, as we have already said, are constructed of a much greater height than that practised but a few years ago comparatively. There are many blast furnace lifts or hoists nearly a hundred feet in height. In one which has a lift of 92 feet, the load of materials, averaging about two tons, is taken up in the space of a minute; and allowing for time in loading and unloading the cages or lifting stages, the weight lifted per hour is 120 tons. The hoist is provided with two cages, one of which is descending with the empty barrows, the other ascending with the full ones. As each barrow is taken, with its load of calcined ore or material, from the calcining kilns or stoves, it is wheeled over a small weighing machine, by which the net weight of the material is ascertained, so that the weight of material delivered to the blast furnace within a given period is thus known. On the arrival of the cage or stage of the hoist at the top of the lift or level of working platform of the furnaces, the loaded barrows are at once wheeled to the platform and to the delivery mouth of the furnaces at the throat. The coke or fuel forming the other part of the "charge" or "burden" of the blast furnace is lifted also to the platform by means of the hoist, the coke being taken from the bunkers at the low level, and wheeled in barrows to the cage of the hoist.

Working Plant of the Cast Iron Manufacture.—Working of the Blast Furnace—Hot Blast Furnaces.

In pointing out what yet remains to be described of the working plant of an iron works, we shall have occasion to refer to the illustrations in figs. 2 and 3, Plate CLXVII., and fig. 1, Plate CLVI., already given. The blast furnace having been provided with the necessary materials constituting the charge, and by means of the structures and mechanical appliances described in last chapter and the process of combustion within the furnace being here supposed to be in full operation, we now glance at the means by which that combustion is maintained at the degree of intensity or of temperature which in a former chapter we saw to be essential to the process of "reduction" or "smelting" of the ore. Reverting to the diagram in fig. 2, Plate CLXVII., the reader will find the position of the appliances required to maintain the combustion in the furnace, or what may be called the "blast-plant," there marked.

THE ROAD MAKER.

HIS WORK IN THE LAYING OUT OF ROADS IN RURAL, SUBURBAN AND TOWN DISTRICTS, THEIR CONSTRUCTION, REPAIR, AND IN THE CHOICE AND USE OF THE VARIOUS MATERIALS EMPLOYED.

CHAPTER X.

AT end of last chapter we intimated, in connection with fig. 23, there given, that the bottom of the ditch might be filled up to a certain line with stones, or in place of this the bottom hollow, as at *a*, might be made a flat stone-lined drain, as *f g h*; the bottom stone, as *i*, being well imbedded in a clay puddling bed, *j j*, and the ends especially being turned for some distance into the puddling. Fig. 24 illustrates another modification, simpler still, in which the watercourse or ditch *b c d e* is provided simply with a trench stone-filled (see the papers entitled "The Land Drainer"). And where the sides of the ditch have got scraped out unevenly, forming a species of flat table surfaces or shelves on which the water lodges, they may

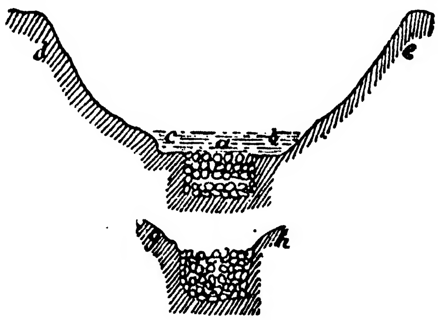


Fig. 24.

be sloped gradually down to the drain *f*, as at *h* and *g*.

Excavations and Embankment Work required in Road Construction.

Having considered the leading points connected with the construction of roads under general or ordinary circumstances—that is, on localities in which, the land being on the whole level, no special works involving expensive construction are required—we now pass on to points connected with another and a more difficult class of roads to construct. In this class, the contour or surface of the country or district through which the road is to be carried varying very much—presenting here hollows and there rising ground — cuttings and embankments are required according to circumstances.

The remarks in the preceding chapters apply only to roads made upon the natural surface of the soil, or with only such an extent of earthwork in their construction as to bring the surface of the soil to its proper form for receiving its covering of stone. It may, however, be necessary, in order to obtain convenient declivities in the direction of the length of a road, that a considerable amount of earthwork be performed in the removal of elevations and the filling up of depressions in the ground over which a road is to be made.

In a cutting, or where the soil is removed, its sides, when not protected by walls, should have a slope of somewhat less than the angle of equilibrium at which the soil in which the cutting is made will stand.

This equilibrium or angle of the natural repose varies in different soils, which are usually assumed to be as follows:—

Fine dry sand	35 degrees
Gravel	37 „
Dry loose shingle	39 „
Dry common soil	47 „
Soil slightly damp	54 „
Soil of the strongest and most compact nature	55 „

The slope of the first three soils named above should have a base of 3 to 2 of height, the fourth of not less than 1 to 1, and the last two of not less than 7 to 8. Rock will generally admit of a perpendicular face. Whenever stones abound, a dry wall of a few feet in height should be built at the toe of the slope of cuttings, to prevent the soil from being washed into the road. It will be necessary in all cuttings to have covered drains at both top and bottom, and also down the face of the slope, in a slanting or diagonal direction, to discharge into the drains along the road at the bottom of the slope. Slopes, when finished, should either be covered with turf or sown with grass seeds, to protect the soil from disintegration by the action of the atmosphere.

Embankments, or soil deposited to fill up depressions, are much better and more solidly formed of successive layers of soil, than by the more usual mode of tipping at the end or sides. Although the former-mentioned mode of forming an embankment is more expensive, yet by it the embankment becomes consolidated, and settles to its permanent form at once; whereas, by the latter, time must be allowed for the embankment to settle before the road can be completed upon it.

It should here be remarked that the bulk in cutting is rarely the same as the bulk in embankment; and the following are the average proportions which the bulk in cutting bears to bulk in embankment of the materials of which such works are formed:—

Rock . .	2 in. cutting	will make	3 in.	embankment.
Clay .	11 „	„	10 „	„
Gravel . .	12 „	„	13 „	„
Dry sand .	1 „	„	1 „	„
Chalk . .	15 „	„	16 „	„

When an embankment is formed, its slopes should be faced with turf or sown with grass seeds.

Having briefly noticed the topics of cuttings and embankments, the preliminary survey which will be necessary in cases where earthwork may be required in the construction of roads may now be described.

The survey referred to should include such dimensions to be taken as to enable a correct ground plan of the site of the road to be made, and a profile of the surface of the ground along the middle or centre line of the intended road to be prepared from levels being taken at every chain's length, and more frequently where any marked or sudden change in the surface of the ground occurs. Cross levels of the surface should be taken at right angles to the centre line of the intended road at the same points at which the longitudinal levels were taken, and each cross-levelling should extend to some distance on each side of the longitudinal line of levels. The dimensions for the ground plan, and the heights taken by levelling for the sections, should be carefully plotted to a sufficiently large scale for correct measurements to be taken from the drawings, as dimensions for required calculations.

There are three distinct cases in which earthwork in the construction of roads may occur: viz., *First*, when the elevations and depressions of the ground are in the direction of the length only of the intended road, the ground being level in the direction of its breadth; *Second*, when the ground, besides undulating in the direction of the length of the intended road, has also a moderate declivity in the direction of its breadth; *Third*, when the side slope of ground is steep. Of the above-named three cases in the construction of roads in which earthwork may be required, the first is that in which the top and bottom of either a cutting or embankment will be parallel and the slopes of the sides will be equal; the only difference between the two kinds of work being that the top of a cutting corresponds to the bottom or base of an embankment. The breadth of the bottom of a cutting and the top of a continuing embankment are always equal, and are called the breadth of the balance line of the work. All the cross-sections, either of cuttings or embankments, are trapezoids, which figure is shown by the diagram (fig. 1, Plate CLXVIII).

Excavation and Embankment Work of Roads (*continued*).—Calculations.

"The perpendicular height and the breadth opposite a given breadth of balance line of a cross section being given, to find the breadth opposite the balance line for any other section of a given perpendicular height."—Multiply the difference between the given breadth and the breadth of the balance line by the given height of the section for which the breadth is sought, divide the product by the height of the section of which the breadth opposite the balance line is given, and the quotient will be the difference of the breadth sought and that of the balance line, which added to the breadth of the balance line, the sum will be the breadth required.

Example.—The breadth of the balance line of a cutting is 24 feet, and the breadth of a section opposite the balance line 30 feet for a height of 2 feet: required the breadth opposite the balance for a height of 5 feet.

The difference between 30 and 24 is 6 feet, the product of which multiplied by 5 is 30, and which divided by 2 is 15, the difference between the breadth sought and 24. The sum of 24 and 15 is 39 feet, the breadth sought.

"To find the area of a trapezoid."—Multiply half the sum of the opposite and parallel sides by the perpendicular height or distance between them, and the product will be the area required.

Example.—Required the breadth of a trapezoid of which the parallel and opposite sides are 39 and 24 and the perpendicular distance between them 5 feet.

The sum of 39 and 24 is 63, the half of which is 31·5, and the product of which multiplied by 5 is 157·5, the area required.

"To find the cubic contents of a cutting or embankment."—Let each succeeding pair of sections be taken —that is, the first and second, second and third, third and fourth, and so on to the last; and in the series of sections let the first and last be 0, as the ends of a separate prismoid, the cubic contents of which is to be computed as follows: viz., Multiply the sum of the areas of a pair of sections added to four times their half-sum by the distance between them, and one-sixth of the product will be the cubic contents of a prismoid between two succeeding sections; and the sum of the cubic contents of all the prismoids, into which the cutting or embankment has been divided by the several cross sections, will be the cubic contents of the whole cutting or embankment.

Earthwork in Road Making.

We now come to the second case of earthwork, or that in which a road is to be made along the side of a declivity of a moderate degree of steepness. This differs from the case last treated of in the cross section of the cuttings, and sometimes also of the embankments, not being a trapezoid. In the present case the section will not have two opposite sides parallel, as in the former case; nor will the sides of the cutting require to have the same degree of slope When, in sloping ground, the inclination of strata of the soil is also somewhat in the same direction as the side fall of the surface—which will generally be found to be the case—the inclination of the strata will be to the higher side and from the lower side of the cutting; the tendency then of the soil to fall will only be on the higher side; and the slope, therefore, will be required to be much greater for the higher than that for the lower side. Fig. 2, Plate CLXVIII., is a diagram of a section of a cutting in the case now under consideration.

THE WORKMAN AS A TECHNICAL STUDENT.

How to Study and What to Study.

CHAPTER X.

In continuation of the remarks made at conclusion of last chapter on the value of a purely moral consideration in relation to technical education, we have further to point out that we have but to remember that in all the labours of man, whether of the brain or of the hands merely, or of both in combination (if indeed intellect can be separated from the most direct of manual labour) we have the peculiarities of human nature to deal with. We cannot, if we would, get rid of them; and if we are wise we would not, if we could, put them aside. They will and do assert themselves continually, and so assert themselves, that in one man they lead him to a complete and fatal failure, and not seldom, acting in one case, they lead according as they have, or are not allowed to have, sway: sometimes to the good, at other times to the bad side of working life, that "chequered and diverse fabric," which with its "weft and warp of many-coloured threads" we find it to be. In all work, therefore, no matter what it be, we find we have this important factor to deal with; and it comes up for being dealt with, therefore, just as much in the work of technical study as in that of any other kind. Some may elect to pay it no concern; to let all their peculiarities have full sway, to allow the pendulum to swing to one side or to the other as it lists, without any desire to put it under regulation. Such will find their lot as students cast in anything but pleasant and profitable places; and as they have sown the bad seed of neglect, so they will reap the harvest of failure and of loss. On the other hand, he who elects to take note of his peculiarities, to study what of human nature *he* possesses, so that he will determine to control such attributes as are calculated to lead him astray, and to cultivate with sedulous care all those capable of directing him in the right way, may reasonably hope to secure some measure of success in the good work he sets himself to perform.

Different Men differently Gifted—Geniuses v. Men but ordinarily Clever, but Steady of Habit—Encouragement to the Latter found in Certain Facts in Business Life.

All are not gifted alike. Some, indeed, are provided with such a slender stock, naturally, of what are good helps to success, that it takes conduct of the highest kind to cultivate them to such an extent as that they may be useful. Others, again, are so constituted that it requires but comparatively little labour on their part to acquire knowledge; or, in other words, study to them is easy, for acquirement is rapid. While there are those so profusely gifted by nature that it seems as if no study at all was required to be given them; so naturally does acquirement of knowledge come to them that it seems as if they had, so to say, only to look at any subject in order to make it their own. Such, who are so generously by nature gifted, the world generally chooses to call and consider geniuses. But it is no little to the comfort, as it adds greatly to the encouragement of those students who are not so naturally clever, to know that, while the business world, the men who create trades and establish manufactures, and open up the many paths of commerce, and give employment to countless thousands, do not value the geniuses of society at the popular, certainly not at their own estimate, they may be ready enough, when challenged, to admit their ability; they are, however, greatly disposed to doubt that this will be applied to any really practically useful purpose. It may be prejudice, but it is nevertheless the fact, that business men do not, as a rule, care to have much to do with those "extra clever young men" who may claim their notice and desire their employment. They are apt to look askance at him who has the reputation of being a genius; for, somehow, they have a shrewd suspicion that, being so, he is not very likely to be a worker. For it is one of the peculiarities of a genius that, being so very clever, having such a facility to master any branch of knowledge he may desire to acquire, to compass any kind of work he may wish to do, he has only, as it were, to look at it, to be able to acquire and to perform; but simply because he thinks that he can do it at any time, the time to do it somehow or another never does come. At least, not seldom is it so: so often, indeed, that business men have, for the most part, decided that the real work of a genius is to pass through life with a supreme confidence that he can work whenever he has a mind, that he can do great things if he but chooses; but that the misfortune of the matter is that he never does choose to do, never has the mind to work. Nor, in looking at the records of past experience, indeed, at the passing circumstances of the day, need we wonder much at this opinion of the business world so unfavourable to the claims of geniuses. There are but few social circles of any extent in any class of society which have not got at least one specimen of the genus "genius"; and we may with some safety appeal to this experience if it be not the case that the geniuses are certainly not distinguished for their practical success in life. Every one concedes their ability, to use the common phrase, "to do anything they set their minds to," but, unfortunately, it so happens that they will not, at least that they do not, set their minds to anything practically calculated to advance their true interests in life.

Far be it from us to decry genius: the world owes much, very much to it; but then it is to genius well directed, soundly and carefully applied to the practical purposes of life. To such is the term truly

and only applicable. Gifted in the highest degree, they have given to them by Him who gives and directs all things wisely and well the still greater gift of steady application, of a determination that they at least, whatever other geniuses may do, shall to the best of their ability make these gifts valuable to society. But, then, the true genius is the very last to put forward the claim that he is a genius; the world it is which makes it for him. It may be taken as an axiom that true genius is ever humble. The reader will remember the beautiful and well-known illustration of this truth in the fact recorded of perhaps the greatest genius which this or any other country ever produced—Sir Isaac Newton—who, when being praised by some one as a great genius, humbly, yet honestly and truly replied, in effect, that after all he was but as a little child wandering by the seashore, who picked up now and then a brighter shell, a finer or larger pebble than was his wont to do; but that the great ocean of truth remained unexplored before him. It is ever so; and it may be said with almost absolute truth that the man—the true genius—who knows the most, is ever ready to admit that he does not know so much, knows only that he knows so little. This was well illustrated (if somewhat paradoxically) by the ancient author who said that knowledge only taught us our ignorance,—that the more we know the more we know that we have to know more. Still more strikingly illustrated, as we think, by a great man, a true genius of our own times, who said that the further we increased the diameter of the circle of our knowledge, we only the more extended the circumference which bounded the wide expanse of the unknown surrounding it. Perhaps the finest example of a mathematical demonstration of a mental phenomenon to be met with.

We have enlarged somewhat upon this point, which may by some be considered as one having but a very remote connection with the leading subject of the present paragraphs. But if a proper consideration of it does not convince those who so think of the truth of the fact, perhaps others of our readers will accept of our assurance of it, if indeed they do not at once perceive it for themselves, that the point bears most closely on our subject, and through it upon the practical success of youth in the business of life. We assert only the common-sense, the business view of the position, when we say that of the two classes of youth about to begin the serious and sober labour of working life, whether that be done by brain or hand or by both combined—the one who is so highly gifted with natural gifts as to be called, or to call himself, a genius, the other possessed only of very mediocre or humble abilities, but who has disciplined himself into, or possesses naturally, patient habits of plodding careful industry—of these two, the vast majority of business men, having employments or situations in their gift, will prefer the latter. And we appeal with the greatest possible confidence to the experience of those who have lived long in the world, and mixed much with its busy workers, if this be not the actual truth. We have, of course, by the first-named of these two classes, supposed that the youth belongs to the class popularly known as that of the "genius," he who possesses the general attributes of that unfortunate class. We do not include in this class the true genius, who possesses the greatest gift of all: the determination to make his abilities of use to himself and his fellow-men. When one of this class appears upon the scene, he, of course, carries everything before him.

But the youth of merely ordinary abilities need not, as, indeed, if he be of the true manly stamp of mind, he will not, grudge the success of the true genius. He may indeed rest prétty well assured of this, that he will not have many competitors of this class, however numerous may be the pretenders to genius, or those who themselves do not pretend to its possession, but really have it, only they make no use of it; these he need not fear. He, at least, will start in life with the impression of business men we have just alluded to in his favour; he will have the chance of progress in life given to him, which business men will be a little chary of giving to that somewhat eccentric and untrustworthy individual, the genius popularly so called and understood. And in this fact lies, as we have said, the greatest encouragement, if it be not a real comfort to the youth possessed only of moderate abilities, but who is determined, God willing and helping, by steady application to make the best of them; who makes up his mind that they shall, when so made, be not only useful to himself, but a trustworthy help to those in whose service he may do his daily labour. On this dual relation the reader may refer with some advantage to what may be said in this work by the author of the paper which considers the technical workman in his daily work in the workshop, factory, or business establishment.

Success in Study one of the Chief Elements of Success in "Business Life."—Entirely Dependent upon the Work of the Student himself.

The reader who has gone thus far with us will perceive, therefore, the point up to which we have been tending: namely, that the success in study, which is the first great preliminary to success in business, and one of the best means for securing it, depends chiefly upon the student himself; that it is not so much a question as to what abilities he may or might possess naturally, but how he makes what he does actually possess of the greatest service.

THE GRAZIER AND CATTLE BREEDER AND FEEDER.

THE TECHNICAL POINTS CONNECTED WITH THE VARIETIES OR BREEDS OF CATTLE—THEIR BREEDING, REARING, FEEDING, AND GENERAL MANAGEMENT FOR THE PRODUCTION OF BUTCHERS' MEAT AND OF DAIRY PRODUCE.

CHAPTER XXI.

Quality of Feeding Stuffs for Cattle (*continued*).

AT the conclusion of last chapter under the above heading we pointed out the influence which prejudice in favour of old-established practice has in deterring some from introducing improved methods. And with regard to the subject of pure water for stock, there referred to, it may be with safety predicated of some that if you were to tell them that dirty vessels out of which to drink, or plates from which to eat, if bad for ourselves, cannot be good for animals, the assertion would at least be met by a smile, if not a sneer,—the very idea of considering animals as subject to the same laws of living as ourselves being new and strange to them.

We have seen the influence which one part of food has upon another, or on some substance more or less or quite foreign, affecting its value as a whole, in going to feed the animal, and to maintain it in good health. We have seen also that certain substances are considered from the chemical view of the question as possessed of no value as nutrition, failing either to support life or add to the production of fat or the formation of flesh. Amongst these inert or useless substances classed by the chemist as such is water. We have endeavoured to show that the water naturally present in foods, and which is popularly called the sap or juice, in place of being an inert or useless substance, is a highly valuable one, playing an important part in the animal economy, as being not only nutritive in itself, but as influencing in a marked degree the value of the other substances present in food, and which by the chemist and the physiologist alike are considered as nutritive. However much the view we have endeavoured to elucidate respecting the water, sap or juice, naturally present in foods may be objected to by some chemists, they will readily admit that water, given in popular language as a drink to cattle, does play a highly useful, indeed an essential part, in the economy of cattle feeding.

Practical Value to the Cattle Feeder of Chemical Research into the Value of Food.

From what has been now stated, towards the conclusion of the preceding chapter, the reader will perceive that there are many things which go far to influence the theoretical value of food used for the feeding of farm live stock. And we have not yet noticed all those modifying influences: what we have yet to give under this head will come more appropriately when we are considering the points which are more closely connected with the actual details of cattle management, in so far as the animals themselves are immediately concerned. Although, however, there are sundry influences, both in the character and condition of the food substances themselves and in the physiological characteristics of the animals which feed upon them, still the researches and investigation of chemists, at whose head stands, as we have seen, the eminent Liebig, the first expounder of the "chemistry of food," have been so minute and so complete, that not only are the individual constituents of food known, but their percentage can be ascertained with such absolute accuracy that the practical feeder of stock has before him statements showing the different and varying constituents of different foods. And by making allowances for such modifying influences as we have already stated, and others we have yet to describe, he can arrive at an estimate of the values of different foods which, if not absolutely correct, will be so far an approach to an approximative value as to be of great service to him in deciding on the details of his system of feeding.

The documents, so to say, on which the feeder bases his practical estimates of the worth to him of the various foods he uses or proposes to use, are the analyses with which chemists have provided him in such copious and complete numbers. All the staple foods, as those grown by the farmers themselves, have been again and again analysed, and so carefully that all concerning them is now known; and the same may be said of at least the best known of the artificial cattle foods, which have been from time to time so freely introduced for the benefit or assumed benefit of the feeder; and it is impossible to overestimate the pecuniary advantages which he has obtained from the researches and analyses of chemists in giving him trustworthy evidence to enable him to decide whether the benefit thus offered by makers of artificial foods were truly so or only for the purposes of trade.

Circumstances affecting the two Leading Departments of Cattle Feeding.

We now come to glance at some of the leading principles connected with two important departments of the practice of feeding which most closely affect not only the present, but the future condition of farming, as regards live stock. We have already alluded to the peculiar circumstances under which the business of farming, considered generally, has been placed during the last few years. Circumstances of so depressing, and withal of so powerful a character, that it has led to a very wide, and in many respects a somewhat too free, that is, a loose discussion, as to whether the character of British farming should be changed, and at once, and that so completely that what has hitherto been an important branch,

namely, arable culture, should wholly disappear, and attention be given only to the department of live stock. And this change is advocated, not merely on the ground that it is one best suited for our climate, which is not a wheat or cereal growing one, at least of the first class, but because the change is the only way in which British farmers can live—that is, meet the competition which faces them from other countries more favourably situated than we are. The points involved are of such national interest that, in addition to what we have incidentally said about it in the course of the present series of papers, we may perhaps find space, before concluding to go somewhat fully into its details. What reference is here to be made to it is made simply because it leads up to a practical point of the utmost importance in the practice of live stock management, which does not merely concern what would be the characteristics of the changed condition of farming above alluded to if the change in its style were universally or generally adopted, but because it influences, and that in the closest degree, the practice of live stock management as carried on at present under the system which has been so long in favour.

Grass Land against Land under Arable Culture.

In the discussion above alluded to the change proposed to be made in the style of British farming, and which it has been somewhat dogmatically asserted was the only change which could save the British farmer from practical extirpation as a class of industrial producers, may be formulated in the phrase which has been in every sense of the term very freely used by the advocates of the change proposed. This phrase, "Grass Land against Land under Arable Culture," is a fair example of that class of popular phrases which are taken hold of and bandied freely about as if they comprised all that need be said on the subjects to which they are appended, and as if the mere statement of what may be called the Shibboleth of the party decided, once and for all, the points at issue. The writer of these lines has always maintained that the discussion of the question involved in this pithy phrase was evidently most keenly carried on by those who had but little practical knowledge of all the points involved. They, indeed, apparently held the notion that there was only one point, and that all that was required to be done in order to give prosperity to the business of British farming was to get rid, as fast as possible, of all arable land—that is, of ploughed or cultivated fields—and replace them by grass land, that is, pasture and meadow fields, but those chiefly pasture.

This notion or opinion, held by so many—we suspect the great majority of the writers on the subject—completely ignored the existence of facts which to the farmer were very plain and important facts nevertheless. In the first place, such writers evidently assumed that arable culture and the growing or culture of wheat were synonymous terms,—wheat, and what are called "bread-stuffs," as Indian corn or maize, being the chief elements by which foreign competition flourished,—it being contended that the British farmer need fear no competition in departments of farming with which live stock were concerned. Do away with arable, replace it with grass culture. But they forget—we should be more correct if we said that many supporters of the new cry did not know—that if the culture of wheat were wholly done away with in Great Britain, arable culture, that is, ploughed or cultivated fields, would still remain as part, and a large part, of the care of the British farmer. The very live stock which were to form the means of his future livelihood demand the produce of this arable culture, to say nothing of the demands made upon it from other sources.

Grass Land Culture.

Again, many of the advocates of the new system of exclusive grass-land farming did not seem to know, or if knowing chose to forget, that points connected with soil, locality and climate, practically precluded land from being successfully laid down as grass land; and they failed to point out what *then* was to be done with land which, in accordance with their predetermined principle, should not be under arable culture, yet could not profitably—in some cases not at all, as grasses would not grow—be put under grass culture. The various points, all of the utmost importance in a practical point of view, will be noticed hereafter in discussing—if space will permit us to discuss—the general question here being considered. But another point has yet to be noticed, and it is one which closely concerns itself with our immediate subject of the general management of fatting cattle and dairy stock. The point which has been also wholly overlooked by those who advocated an indiscriminate or universal adoption of grass-land culture is this: that grass, *per se*, is not the *only* food upon which live stock are fed and reared; further, that while it is only one of many kinds of food used by the live-stock farmer, it is not the best food—far, indeed, from being the best. Further, that even giving it the highest value as a food, this value is very fluctuating, and this of necessity arising from the qualities of the grasses, and not merely from bad farming, but also from the fact that in certain soils and under certain climatic and local influences the farmer cannot grow good, that is, nutritive grasses, however anxious and able to do so. Further still, and granting that the farmer possesses grass lands bearing the best and the most nutritious of grasses, it does not follow—as so many of the uncompromising advocates of the great change in the style of British farming seem to decide

that it does follow—that the only way of using those grasses, that is, feeding live stock upon them, is to allow the animals to pasture in the fields. This point, and all the important practical considerations outcoming from it, is the point which now demands our attention. The most advanced farmers have for long held the opinion that pasturing, or eating off grass by allowing live stock to roam at will over the fields which produce it, is the least advantageous of all methods of using it; and this opinion is extending daily. As the question is concerned in the closest manner with that of the general management of farm live stock, and as its consideration brings up with it that of a system or of other systems of feeding stock which take its place, we now propose to go somewhat fully into it.

The Pasturing System of Feeding Stock.—The Points involved in the Question.—Defects.

One acknowledged defect of the commonly adopted method of pasturing cattle or dairy cows is the large percentage of loss incurred by it. The animals in feeding off the pasture grass roam all over its surface, and the mere treading of the grass by their feet, especially in very or long-continued wet weather, brings about a large amount of loss. But this is not all. Wherever the droppings of the animals fall—and they generally cover a large space of ground—the grass is, for the time being, killed. It is only after a considerable period, when the dung is decayed and broken up by weather influences, that the grass grows again on the same space. No doubt it may be said that the very richness of the manure which the droppings give to the soil causes such an increased growth of the grass around them that the weight of this heavy growth will amply compensate for the loss sustained by the grass not growing on the surface actually covered by droppings. This would be true, only for the unfortunate circumstance that the grass,—which is specially the result of the rich manure—which grows *around* the heap of droppings, is, while luxuriant and heavy in growth, so rank and strong that the animals will not eat it if they can get any other grass not so produced. The same applies to the grass which in time grows *through* the heap of droppings. Those droppings being numerous in proportion to the number of cattle pastured out in the field, cause a loss of productive land which, taken in the aggregate, amounts to a percentage of the whole produce very serious in amount. The evils of the "droppings" are attempted to be got rid of, in well managed farms, by breaking up and scattering their contents over the adjacent surfaces, thus giving so far the benefit of a good manuring to a wider space of grass land. But this breaking up of the droppings can only be done after they have got so far dried up and consolidated that they can be treated by the fork or implement so that they can be spread over the ground in small lumps which form a good dressing of manure. And while consolidation is thus going on, the stoppage of the growth of grass below is going on.

But this is not the only loss incurred in the pasture system of feeding stock. The liquid droppings of the animals cause a further loss of feeding surface. No matter how sweet and rich the grasses may be on any given space of the pasture, when the liquid exuviæ of the animal is passed over it, it will no longer look at the grass as an edible; nor need this be wondered at. And on such spots so voided on, the grass for the time fails in growth, and when this begins again, it is so luxuriant, yet rank, that the animals will not eat of it, or do not eat readily or appetisingly of it; and where there is no keen appetite, there is always a loss in feeding them. Not only do the droppings and voiding of the animals do harm to the pasture grasses, but the value of the manure which those droppings and voidings form is to a large extent lost. The great object to be secured in manuring pasture and grass lands is to spread the manures, whether farmyard, artificial or compost manures, as uniformly as possible over the surface; and at such a given rate or weight of manure to the acre as is deemed requisite under the circumstances. Now, it is obvious from what we have said that there is no uniformity of deposit and no spreading of the manure created by the animals as they are feeding on the pasture grasses. There can, moreover, be no choice as to the period of application of the manure, and there is no one period better than another when the full benefit of the manure applied is secured by the succeeding crop. Taking all the circumstances connected with the manure produced by the animals in the pasture fields, it may, with some degree of accuracy, be estimated that nearly if not quite one-half of its value is lost by the system of feeding stock. What may be called the average irregularity with which the manure is deposited by the animals on the field is greatly aggravated in certain places, such as in favourite shelter places under trees, and at or near gates where the animals often congregate. Here there is a large deposit of manure, which may be said to be almost wholly lost so far as any good it does to the pasture land. We see, then, from all these facts of practice, that the system of pasturing cattle is not the most economical, indeed it is the most wasteful, way of applying manure, and that this of necessity involves a large waste of grass which under other circumstances could be made directly available as food by the animals.

THE SANITARY ARCHITECT.

The Principles and Practice of His Work, in Healthy House Arrangement and Construction.—Technical Points of Sewerage and Drainage, Ventilation, etc.

CHAPTER VIII.

At the end of preceding chapter we pointed out that it was necessary, in the case of the proprietor of house property, that he should at least have the best advice on the subject of house drainage. He also, however, has to trust to the workmen that they have done their work well; and he can only judge of the facts that they have or have not done it well by the general circumstances attendant upon the operation of the system. Many details may, however, have been so far scamped over that the system as a whole may operate well for a time, but be so inefficiently carried out in regard to permanency that before long faults will begin to show themselves. After all, we are driven to place our reliance upon the good faith and honesty of all the workmen engaged.

Two Stages or Periods in the History of the Art of House Draining.

If space had permitted us to trace the history of the art of house draining from the earliest times up to those which approach and, indeed, in some respects, form part of the times we live in, we should have, in so doing, met with much that was more or less directly and incidentally practically useful and suggestive, bearing closely upon the principles and practice of what has now come to be considered as the art and science of modern house or town drainage. But we may suppose that we have done this, and have arrived at a point in the practice of the art in which we find that there are two eras or stages, each of which is characterised by its own striking and peculiar feature. The earliest stage or era of house and town drainage was that in which all the channels for the conveying away of the liquid refuse of houses from their immediate neighbourhood to the place of final deposit—which was always the nearest river or stream, or the sea if the town was on its margin—were simply ruts or gutters cut in the surface soil; and this whether they were the main channels placed in the streets or public ways, or the subsidiary or branch or lateral channels leading from the houses to the main channel. This stage or era of house drainage practice may be designated the "gutter," or perhaps, as still more distinctive, the "open or surface channel" period of the art. We might, if space had permitted, have detailed the circumstances or probable circumstances which led of necessity to the doing away with the open or surface channels, and the substitution for them of channels or drains which, however near the surface they were placed, were still, being covered up or built over, to be considered as underground or subterranean liquid refuse or sewage courses or channels or drains. This system constituted the second stage or era in the progress of house drainage practice, and may be designated, in contradistinction to the first era above named, as the "closed or covered-in channel" system.

Characteristics of the Two Systems of Early House Drainage as bearing upon the Modern System.

The reader will perceive, in glancing at the easily remembered characteristics of each system, that in the first or "open or surface channel," whatever faults in other ways it possessed, it certainly had two great advantages. No matter how made, whether as simple ruts dug out of the surface soil, or formed with greater constructive skill, with solid sides and bottom, the channels—or gutters, to call them by their best-known name—being open throughout their whole length, could be cleaned out if cleaning was considered desirable. Or if their cleaning out from time to time was not looked upon—as in the early days it was not likely to be so—as a duty to health, the removal of obstructions to the flow of liquid refuse along them would be an easy matter. And these obstructions would be found more frequently at some points than at others. However far the cleaning out of the gutters was carried on, either as a necessity or a duty, or whether it was as a rule neglected, the very nature of the open gutter gave at least every facility for cleaning them out. Their condition and what obstruction might be present could at least be seen,—so that our ancestors had not the excuse so often made by us, that they did not know of the faults or evils existing in their system of open gutters.

The second advantage of the open gutter or surface channel system was this. That wherever, whether at any one particular point or along the whole course of a gutter, gases or emanations from putrefying materials or decaying substances arose, they were at liberty to ascend and mix freely with the surrounding atmosphere. And the gases thus created would begin to ascend as soon as they began to be created,—that is, they would be of comparatively small volume at first, and be of a less pungent and disgusting odour than if they were kept in and fenced, so to say, to be concentrated and made more intense. No doubt the longer substances liable to putrefy or decay were allowed to lie quiescent in the open gutters, the worse their condition would become, and the more pungent would be the putrescent odours. Still, as we have seen, they would have the chance of being moved along by some accession to the liquid, as by a shower of rain,—the chance, moreover, of being removed by hand where they were peculiarly offensive. At all events, the putrefying substances could be seen, and their exact position further indicated by the sense of smell. But in all cases, and as well in their most

offensive as in their simplest condition, this great advantage was present—that the principle of "diffusion of gases" could operate at any time and in the readiest of all ways. The law of diffusion of gases in the atmosphere—discovered, or at least first explained, by Dalton—is one of those provisions of nature so wisely ordained by a beneficent Creator for the physical well-being of man. By its operation gases, no matter what may be their nature, are mixed or commingled with, spread or diffused through the mass or volume of the common air or atmosphere. And this diffusion exists to an extent and for purposes the most beneficent to man; which many have no conception of, and of which, if this were the place or space permitted, we could give many and striking examples.

Some Characteristics of Unhealthy Gases or those from Drains.

Poisons are all the more dangerous, and act in the most rapid and conclusive way, the more concentrated they are. A dose of a liquid poison which in its natural or concentrated condition would kill a strong man in a few seconds, if mixed, diluted with or "diffused" thoroughly amongst a large bulk of water, would be so innocuous that a puny infant drinking a portion of the mixture would not be injured. The same holds good of aerial poisons or gases, which if breathed in a highly concentrated condition would kill a man or render him unconscious instantaneously, but if diffused with a large bulk of common air, or the general atmosphere, might be breathed, if not with absolute and final impunity if inhaled for a long period, at least without immediately dangerous or fatal consequences. But there is this essential difference in the two poisons, the liquid or gaseous, so far as their weakening is concerned by being mixed with large bulks of innocuous liquids, as water, or with an innocent gas, such as the common air. The mixture of the liquid poison with a bulk of water takes a comparatively long time for completion, and generally requires a shaking or agitation of a more or less violent character to effect a complete and equal diffusion of the poison throughout the whole mass of the water, so that any one portion of it would possess the same amount or percentage of the poison as any other portion taken at random. But in the case of the mixture of an aerial poison or noxious gas with a large bulk of the common air or atmosphere, the diffusion of the poisonous gas through the mass of the atmosphere begins at once, and is so rapid and complete that the poison may be said practically to be immediately lost or got rid of. For example, the formation of that deadly gas or aerial poison known as carbonic acid in a close confined room, by the combustion of charcoal in an open brazier, is so rapid and dense, so to say, that people sitting in the room would become quickly drowsy and soon be killed. But so rapid is the diffusion of this deadly gas with or amongst the ordinary air, that, almost immediately upon the opening of a window which will admit of its entrance, those under the influence of the gas, if not actually killed, will begin to revive, and the air of the room will become pure and fit to be breathed with absolute impunity in a marvellously short time.

Practical Bearing of Foregoing Points on the Art of House Drainage.

The bearing of these facts upon the question of house drainage and also upon another important branch of sanitary science—house ventilation—is of the closest and most practical kind; and if it be well considered, many of the points connected with the practice of the art of drainage involved in it will be so clearly apprehended that the necessity for their fuller explanation further on will be done away with, and our space and the time of our readers saved. The advantage of the open gutter or surface channel system of house and town drainage will now be perceived as favouring in the most direct and rapid way that diffusion of the gases arising from the putrescent matter present in the gutters or channels which dilutes or weakens them to a point no longer dangerous. And that the gases arising from putrescent matter are in fact aerial poisons, no one now-a-days will be inclined to dispute,—although it is worthy of remark, as characteristic of one of the mental peculiarities of man, that we submit to breathe such aerial poisons all the while that we know that they are poisons, and this so long as their effects on the system are not obviously and directly dangerous. It is quite true that, from the very extent or area of the surface channels or gutters, this, the first system of house drainage, would give rise to large volumes of aerial or poisonous gases, these being created in a way more or less offensive or dangerous in proportion not merely to their area but to the way in which and the length of the intervals between which the gutters were cleaned by hand, or flushed or washed out by Nature with her beneficent rainfalls. The extent to which the general air of a town could be contaminated, or at least rendered notorious as being the reverse in sweetness to the "balmy gales of Araby the blest," or "Sabean odour from the spicy shores," is illustrated in the case of of the well-known town of Cologne, on the banks of the Rhine. Coleridge rendered the air or the memory of it immortal, when, in his own graphic way, he described it as being made up of "thirty special and distinct stinks," each so marked that it could be distinguished from its fellows.

THE STEEL MAKER.

The Details of his Work—The Principles of its Processes—The Qualities and Characteristics of its Products.

CHAPTER XI.

The "Converter" of the Bessemer Steel Making Process.—Its Practical Use.—Process of Conversion.

The converter has, at the commencement of the process, its interior brought to a red heat by consuming coal in it. It is then swung round till it assumes the position in fig. 2, so that the melted pig from the cupola furnace can be easily run into the interior of the converter by means of the trough *h*. When it has received its proper supply, the converter is again swung round, till it assumes its normal position, as in fig. 1, which it retains during the process of conversion. The blast is, however, turned on before the converter is made to resume the position as in fig. 1; the object of blowing through before the converter is made to assume the vertical being to prevent the fused metal running through the holes *d* in the

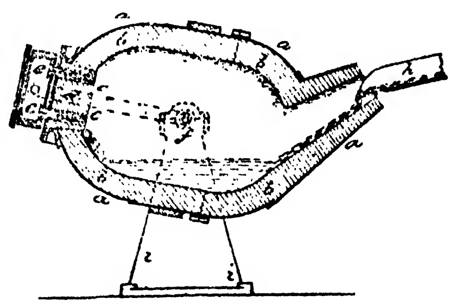


Fig. 2.

bottom, *c c*, upon which it rests, and to pass which is of course its natural tendency. This, however, is obviated by the blast, which is powerful enough to keep the molten metal above the perforated bottom, and by bearing it up, or keeping it suspended, as it were, to thus prevent it passing through the holes to the blast chamber *e e*.

The converter is now swung round so as to assume its normal or vertical position, as in fig. 1; and the powerful blast going on, the stages of the process of "conversion" are as follows. The immediate action of the blast projected into the interior of the converter through the apertures in the bottom, *c c*, is to send out a fierce and long flame from the mouth *g*, fig. 2.

We have not space to describe the truly wonderful sight which is presented to the spectator in the course of the "blast," but while its splendour is painful to the eye, it is "yet so fascinating that few who have seen it for the first time can resist it and turn their dazzled eyes away." After a certain stage of the brilliant blast has been reached, the melted spiegeleisen is poured into the converter, which creates a new display of flashing flame. This finishes the process: the Bessemer iron is now made, and is cast into ingots. For a lucid and most interesting description of the various changes which take place within the converter during the "blow" or blast, and of all the fiery splendours with which it is accompanied, we must refer the reader to Mr. Williams' papers, read as one of the Cantor lectures before the Society of Arts in 1876—on "The Iron and Steel Manufacture."

In a paper read before the Institution of Mechanical Engineers, shortly after the difficulties attendant at first upon the process had been overcome, and it had established itself beyond all doubt as an invention pregnant with the most important results to the trade, Sir Henry (then Mr.) Bessemer gave an account of apparatus erected at the Atlas Steel Works of Messrs. John Brown at Sheffield, to carry out the new process. This, as described by Sir Henry, will, in conjunction with the drawings in figs. 1 to 9, give the student a good idea of the mechanical appliances and general arrangements of a Bessemer steel making plant some two-and-twenty years ago. The drawings here referred to have been prepared from drawings given by Sir Henry Bessemer in the paper above alluded to.

"The crude pig iron chiefly used in this process has been the hot-blast hæmatite pig smelted with coke, which is melted in a reverberatory furnace adjoining, and is then run into the converting vessel, *a a a a*, figs. 3 and 5, in which its conversion into steel is to be effected. The "converter" vessel is shown enlarged in action in fig. 4, which represents its position in being filled, the melted pig iron being run into it by the spout *h*, fig. 2, direct from the furnace. It is made of stout boiler plate, and lined with a powdered siliceous stone found in the neighbourhood of Sheffield below the coal and known as "ganister." The rapid destruction of the lining of the converting vessel was one of the great difficulties met with in the early stages of the invention: the excessive temperature generated in the vessel, together with the solvent action of the fluid slags, was found to dissolve the best firebrick so rapidly that sometimes as much as two inches thickness would be lost from the lining of the vessel during the thirty minutes required to convert a single charge of iron into steel. The ganister now used, however, is not only much cheaper than firebricks—costing only 11*s*. per ton in the powdered state—but it is also very durable: a portion of the lining of the vessel is shown which has stood ninety-six consecutive conversions before its removal. The converting vessel, *a a a a*, is mounted on bearings which rest on stout iron standards, *i i*, fig. 1, and by means of gearing and handle it may be turned into any required position. There is an opening at the top for filling and pouring out the metal; and at the bottom of the vessel are inserted seven fireclay tuyères, each having seven holes. The

blast from the engine is conveyed through one of the bearings of the vessel, fig. 1, into the tuyère box *e e*, and enters the tuyères at a pressure of about 14 lb. per square inch, which is more than sufficient to prevent the fluid metal from entering the tuyères.

"Before commencing with the first charge of metal, the interior of the converting vessel is thoroughly heated by coke, with a blast through the tuyères to urge the fire; when sufficiently heated it is turned upside down and all the unburnt coke falls out. The vessel is then turned into the position shown in fig. 2, and the melted pig iron is run in from the surface by the spout *h*, the vessel being kept in such a position, during the time it is being filled, that the holes of the tuyères are above the surface of the metal. When the proper charge of iron has been run in, the blast is turned on and the vessel quickly moved up into the position shown in fig. 2. The blast now rushes upwards into the fluid metal from each of the forty-nine holes of the tuyères, producing a most

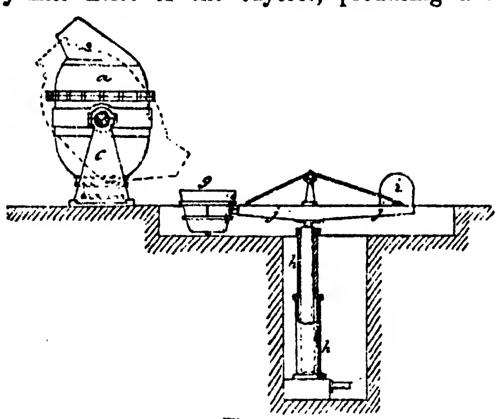


Fig. 3.

violent agitation of the whole mass. The silica, always present in greater or less quantities in pig iron, is first attacked, and unites readily with the oxygen of the air, producing silicic acid; at the same time a small portion of the iron undergoes oxidation, and hence a fluid silicate of the oxide of iron is formed, a little carbon being simultaneously burnt off. The heat is thus gradually increased until nearly the whole of the silica is oxidised, which generally takes place in about twelve minutes from the commencement of the process. The carbon of the pig iron now begins to unite more freely with the oxygen of the air, producing, at first, a small flame, which rapidly increases, and in about three minutes from its first appearance a most intense combustion is going on; the metal rises higher and higher in the vessel, sometimes occupying more than double its former space, and in this frothy fluid state it presents an enormous surface to the action of the air, which unites rapidly with the carbon contained in the crude iron and produces a most intense combustion, the whole mass being, in fact, a perfect mixture of metal and fire. The carbon is now burnt off so rapidly as to produce a series of harmless explosions, throwing out the fluid slag in great quantities; while the combustion of the gases is so perfect that a voluminous white flame rushes from the mouth of the vessel, illuminating the whole building, and indicating to the practised eye the precise condition of the metal inside. The blow-

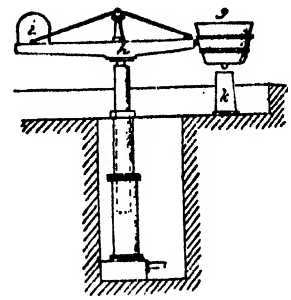


Fig. 4.

ing may thus be left off whenever the number of minutes from the commencement and the appearance of the flame indicate the required quality of metal. This is the mode preferred in working the process in Sweden. But at the works in Sheffield it is preferred to continue blowing the metal beyond this stage, until the flame suddenly drops, which it does just on the approach of the metal to the condition of malleable iron: a small measured quantity of charcoal pig iron, containing a known proportion, is then added, and thus steel is produced of any desired degree of carburation, the process having occupied about twenty-eight minutes altogether from the commencement. The converting vessel is tipped forwards and the blast shut off for adding this small charge of pig iron, after which the blast is turned on again for a few seconds.

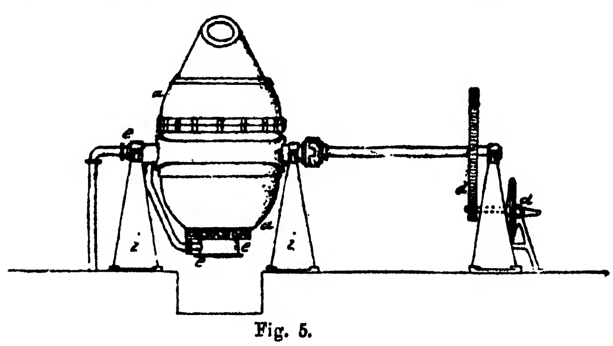


Fig. 5.

"The vessel is then turned into such a position that the fluid steel run into the casting ladle *g*, fig. 3, which is carried by the hydraulic crane *h h*, is counterbalanced by the weight *i*, on the opposite end of the jib *j j*. When all the metal is poured out of the converting vessel, the crane is raised by water pressure and turned round, as shown in fig. 4, for the purpose of running the steel into the ingot moulds *k*.

THE FACTORY OR MILL HAND AS A TECHNICAL WORKER.

The Organisation, General Duties, and Special Work of the Staff of Factories for the Production of Spun and Woven Goods—that is, "Yarn" and "Cloth"—and those chiefly in Cotton and Wool—General Description of the Various Processes of Manufacture.

CHAPTER XIII.

In fig. 10, at end of preceding chapter, we gave a diagram illustrative of the "slubbing frame." According to the fineness of the rovings required, several slubbing machines are used before proceeding to the spinning mule or throstle. These are called "slubbing machine," "intermediate frame," "roving frame," and "jack frame." An important improvement in the flyer is the presser-flyer, by which the arm for winding the yarn on the bobbin is provided with a smaller arm, fastened by a spring, through which the yarn runs, and which likewise presses against the yarn whilst it is being wound on the bobbin. Through this the rovings are not only made closer, but a larger quantity can be wound on a spool. Another very clever contrivance in this machine is the arrangement by which the variation in the velocity of revolution of the spindle compensates for the increasing diameter of the bobbin. From the differential motion secured by the mechanical contrivance, these slubbing machines are sometimes called "differential" slubbing frames.

On the frame *a*, fig. 10, there is a drawer *b*, as before described, through which the rovings from the bobbins, *a*, *a*, pass on their way to the flyer *b*. This they enter by the funnel-shaped hole at the top of the spindle, pass through the hollow arm *d*, and pass out through the side opening of the presser arm *c*, by which they are pressed against the bobbin *e*. Whilst the rovings are being wound on the bobbin, the platform carrying these is lowered and raised by the wheels *f*, *g*, *h*, *i* and *k*, shown in the figure by dotted lines. As the wheels *i* and *k* must likewise rise and fall continually, and as they must always be in connection with the other wheels, *f*, *h* and *i*, the latter are connected by a crank-joint *l m*. The spindles are made to revolve by toothed wheels placed at their lower ends. According to the amount of twisting it is desired to give the rovings, the spindles make from 200 to 800 revolutions per minute.

An improvement, for making the motion lighter, increasing the speed, and consequently increasing the production of the machine, was made by William Higgins in Manchester in 1861. Whilst the spindles usually revolve in fixed sockets and independent collars, which together with the fixed arm move up and down, Higgins has given these parts a motion at right angles to one another, and supported the bobbins by iron supports reaching to their middle. Through this improvement an irregular movement of the platform can never cause the spindles to jam in their collars, and as the collars do not move up and down on the spindles themselves, but on their supports, the spindles revolve safely at the upper ends of their supports; they can make 1,000 revolutions in slubbing machines, 1,500 in intermediate frames, and 2,000 in roving frames.

In connection with this came also an improvement in the centrifugal "presser." This is a wire with a short arm or finger at the end of a hollow flyer, and which is pressed against the threads of the spool as it revolves. In order that, if the spindle were suddenly to stop, the presser should not fly off and break or sprain the rovings, it is balanced upon a sloping plane of the flyer, and weighted at the other end. This weighting would cause the flyer to rise up were it not prevented by its own weight. For further explanation the accompanying figure (11) will serve. *a* is the spindle, *b* the flyer, *c* the bobbin, *d* the support going to the middle, upon which the collar attached to the joint *f* slides when the platform *g* rises or sinks. *h* is the presser, with the finger *k*, and is suspended from the sloping plane *i*.

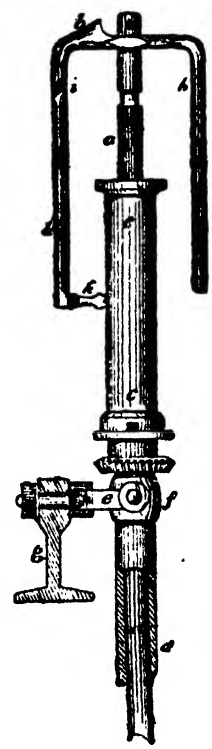


Fig. 11.

Details and Practical Management of the Slubbing Process of the Cotton Yarn Manufacture.

In passing from the drawing frame to the slubbing frame in all coarse spinning mills, and some mills where

medium counts of yarns are spun, and where a good clean quality of yarn is to be produced, there comes in a machine called a "combing machine"; but we shall pass on to the process of coarse or medium counts spinning, commonly called "carded yarn." Our remarks on the combing machine will follow at a later stage, if space will permit.

The "slubbing frame" has altogether a different aim to that of the drawing frame in its arrangements and its purpose. The drawing frame is not intended to reduce the sliver in thickness, though in some rare instances the sliver at the last head of drawing is slightly lighter than it was when it left the carding engine. We have already described the functions of the drawing frame. The slubbing frame performs three things, which are its special aim: the first is to reduce the sliver in thickness to about one-fifth that of which it was when it left the drawing. The sliver being drawn out to such an extent, it is then of course very thin. The thinness of the sliver and that of the fibres lying side by side, it is then not strong enough to carry its own weight for or to any other process, and therefore the second object of the arrangement is brought into operation—that of "twisting the sliver" as it leaves the rollers—and thus the twisted sliver, being so reduced, forms a sliver or roving in the form of a single strand, and in this state it is wound upon a bobbin. When the bobbin is full it is removed from the spindle and an empty one supplied. Thirdly, the winding-on of the roving to a bobbin, by the means of a flyer which is attached to the spindle, and the revolution of the spindle and bobbin, twists the drawn or thin sliver as it leaves the rollers where it has been drawn, and it then passes down a hollow tube in the leg of the flyer. The flyer is in shape like a two-legged fork, only one leg of the fork is hollow. The hollow leg contains the roving, and thus keeps it from flying about and being entangled with any other part, either of the flyer or spindle. The slubbing frame, like that of the former machinery named, is driven in the first place by a belt or strap, and the rollers receive their motion from the belt shaft by means of wheels, and therefore they are driven by tooth and pinion. In the same way and from the same shaft are the spindles and bobbins driven. The spindles and bobbins are driven independently of each other. The necessity of this will be evident to the reader when he reflects that the spindle and roller have to be so connected as to keep the same amount of twist in the roving throughout, and the bobbin has to be so speeded as to take up the sliver always at the same tension; the bobbin and the spindle, one giving the twist and the other taking up the roving, there must be some system of altering the relative speed of each. An arrangement is so contrived that for the completion of each layer of sliver on the bobbin, the latter requires a different speed. A change in speed is accomplished by means of conical drums, and a motion in connection with them called "differential." This can be set to the greatest nicety by the change of a wheel.

The cotton sliver, or coarse partially twisted thread, as it may be called, is then in a convenient condition for transporting from the slubbing frame to the next frame—"intermediate."

The Intermediate Slubbing Frame.

The slubbing frame may be said to have more complicated machinery about it to carry out the third part—that of winding-on of the sliver or thread part to a bobbin. The frame part of it is of course so arranged as to be convenient to embrace all the working parts. The slubbing frame is so constructed that the cans containing the slivers after being drawn at the drawing frame can be conveniently arranged along the whole length of the frame. The sliver from each can is put up to the rollers, and is thus carried through and drawn in the rollers precisely as in that of the drawing-frame rollers; the only difference in the rollers of the two frames being that the drawing frame has in its arrangements four rows of rollers, while the slubbing frame has but three rows. The process of drawing is the same, excepting that the drawing frame draws six ends into one, and the slubber draws but one end with a draft of about five—*i.e.*, it draws the sliver to five times the length at the finish of that at which it was when it left the drawing frame. The slubbing is really the first process which reduces the sliver to any appreciable extent. The slubbing frame has two rows of spindles, one row behind the other, but not directly so,—more in a zigzag form, so as to receive the sliver in a direct line from the roller to that of the top of the spindle, where it enters the flyer, without coming in contact with another, and also for the convenience of driving the spindles, as each row is driven from separate shafts. The slubbing frame varies in length, perhaps more so than in any other frame which follows. Seldom are slubbing frames made with less than thirty spindles in, and seldom with more than sixty. The slubbing frame being the first frame to reduce the sliver in thickness, it will be seen that the sliver will in this case be thicker, and therefore the roving have less twist in it per inch, and in this way the bobbin on which it is wound is sooner filled. To meet this incident a larger bobbin is used—*i.e.*, a longer one in lift (length), and also much thicker when finished. One spindle of a slubber will supply about four spindles of the frame which follows (the intermediate), from which it will be seen that the slubber does not require to have so many spindles in it as that of the finer frames which follow.

THE BRICKLAYER OR BRICKSETTER.

THE PRINCIPLES AND PRACTICAL DETAILS OF HIS WORK.

CHAPTER XIII.

Piers and Chimney Stacks.

IN fig. 4, Plate CXLVI., we give at A the first course, and at B the second course, of a pier built hollow, the hollow space in *a b c d* being fourteen inches square, the outside wall being a brick thick. Fig. 5, Plate CXLVI., diagram A, is the elevation of the side *g i*, B of the side *g h* of fig. 4. Fig. 6, same Plate, may also be taken as the first and second courses of a "flue" or chimney stalk—a 9-inch-by-14 one, the thickness of outside wall being one brick. Of these two plans we give part side elevation in A, *fig.* 7, Plate CXLVI., and in B part end elevation. In fig. 1, Plate CLIV., at A we give plan of first course of a "chimney stalk," or a "hollow pier" of which the length is greater than the breadth. If fig. 1, Plate CLIV., be taken as the plan of a chimney stalk, it gives a flue *a*, 14 inches by 9, and a second flue *b*, 14 inches square; in B, fig. 1, Plate CLIV., we give the second course; in fig. 2, same Plate, in A the elevation of the courses of the side *c d*, fig. 1, Plate CLIV.; and in B, fig. 2, Plate CLIV., elevation of the end *c e*, fig. 1, Plate CLIV.

Pointing.—In finishing off the outside faces of brick walls, the operation of pointing is resorted to; this consists in filling up all the joints with a superior mortar, and in the best class of work with cement. To properly "point" a wall requires great care, and indeed skill, where thorough neatness and finish in the joint are to be secured. Moreover, pointing requires to be conscientiously done, for much of the capability of a wall to resist the action of damp and of driving rains depends upon the way in which the joints are made good. The first operation of "pointing" is to remove all the mortar from the face of the wall which has been pressed out from between the bricks (or stones) in placing them in bed; the mortar is next removed from between the joints, and for some distance inwards, this being done in order to give a "key," bond or hold for the mortar or cement with which the pointing is done. The joints between the bricks (or stones) being thus opened up, the loose dust is next blown or brushed out, and the mortar or cement is inserted carefully into the joint, and pressed well up into the cavity so as to get a good hold. There are more ways than one of finishing off the outside of the joint or of its face. What is called a "rule joint," —"pointed and finished off with a flat rule joint,"—is done by bringing the mortar or cement a little forward

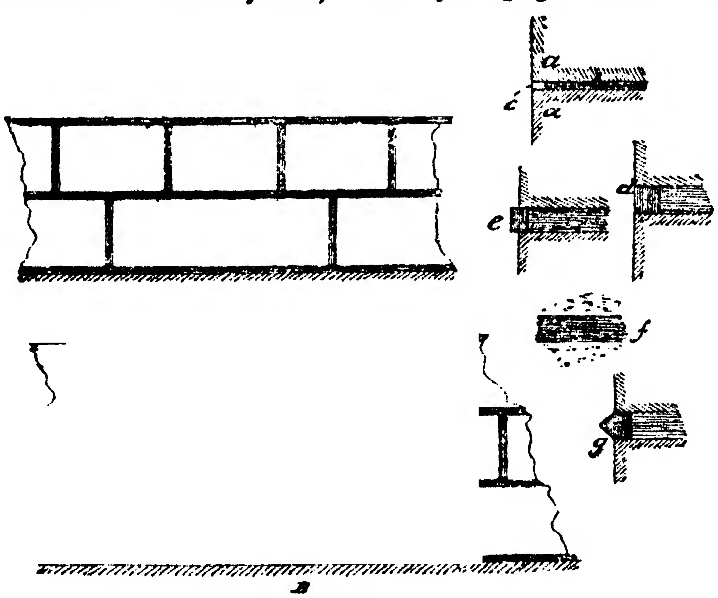


Fig. 37.

in front of the face of wall, and finishing its lower and upper edges perfectly square and level by means of a flat straight-edge or rule applied to the joint, as shown in diagrams A and B, fig. 37, which represent pointed work in "Old English" and "Flemish" bond respectively. The diagrams to the right of this figure illustrate "pointing": *a a* shows two adjacent bricks, with the mortar between them represented by a thick line; part of this is picked out in front, as at *c*, and the space filled up, as at *d*, with fine mortar or cement; and when flush with the surface of the wall, as shown, it is called plain pointing, but when filled in with a part projecting, as at *e*, and finished as above described, it is called "rule" pointing, shown in front view at *f*. The diagrams A and B will perhaps enable the student to decide for himself the much disputed point, already alluded to, as to whether the "Flemish"

bond, as in B, is so much more beautiful or pleasing to look at than the "Old English" in A. All this is done with the point of a finely pointed trowel. In some classes of brickwork the cement used for pointing is mixed with a proportion of lampblack: this gives the wall a series of horizontal and vertical lines (of the joints) in black, which is by some supposed to impart a higher finish or look to the wall than when the mortar or the cement is left its natural colour. In "rough pointing" the outer face of the joint after being filled up as above described is finished off simply with the point of the trowel, without the application of the rule or the straight-edge. In some cases the face of the joint is wrought to a point or sharp arris or edge, as at g in fig. 37, this being done to throw off the water from the joint; but such methods as this have not been successful. What is called "flush pointing" is literally facing a wall with a coating of cement, generally Roman cement, to enable the brickwork the better to resist the weather, or to conceal the fact that the wall is of brick, and to induce the belief that it is stone—a "make-believe" or sham which

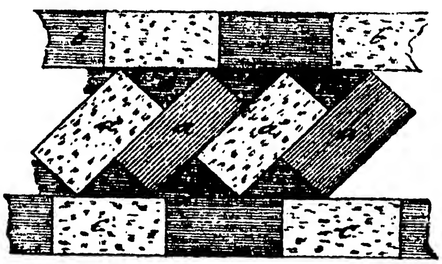


Fig. 38.

is always a failure, as all shams deserve to be. It is altogether a mistake to suppose that a cemented house front would look better than a brick wall. Brickwork well executed is in itself a beautiful object—infinitely more so, at all events, than a cemented front purporting to be stone, which nobody is deceived by, and which, from the cement used being generally of bad quality and scaling or peeling rapidly and irregularly off, gives a look which is beyond mistake shabby, and tells its own tale. Even if the brickwork be not well pointed or pointed with a rule joint, if it is good—that is, the bricks sound and well laid—it looks better, and this if for no other reason than that it looks what it is, and carries no pretence with it. It is honest-looking work, which cannot be said of cemented work, with which, either from a constructive, an æsthetic, or a moral point of view—the latter when the purpose of cement is to deceive—we have not the slightest sympathy.

Diagonal Bond.

In addition to the classes of bond we have illustrated, there are several others, some practised on the Continent, where brickwork has received its best and widest developments, some in this country. The bond used in certain species of hollow brick or cavity walls may be called an extra or new variety. Although not new, having been long practised, are the bonds known as the "diagonal" and the "herring bond"; the latter, indeed, may be classed amongst the oldest of bonds, —the diagonal being but a variety or sub-class of it. This—the "diagonal"—is illustrated in fig. 38. It is chiefly used for filling in the interior spaces of brick walls or courses, such as those of foundation courses. It is obviously not applicable to walls of inferior thickness or depth from front to back, as there must be room in the interior spaces in each course—that is, between the line of inside and outside bricks—for the diagonal bricks to lie in. The minimum depth from front to back in the thickness of wall is that equal to two bricks long, and the bond invariably used or that adapted to diagonal work is Old English—that is, alternate courses of headers and stretchers. The angle at which the diagonal bricks lie, as $a\ a\ a\ a$ in fig. 38, is that of 45°, but if the student will make up some courses in model bricks giving different thickness of walls, he will find that the angle will have to be varied according to circumstances. The illustrations in figs. 38 and 39 (for the latter of which see next chapter) are not designed to show further than the arrangement of the diagonal bricks and their relation to the outside course of bricks which form the inclosing space within which the diagonal bricks lie, such as the stretchers $b\ b$, $c\ c$. It will be observed that, whatever be the angle at which the diagonal bricks lie in relation to the outside bricks, they will only touch the inside of these inclosing bricks at points, and will form angular spaces, as $d\ d$, shown in black in the diagram. These spaces will vary in size and outline according as the angle of the bricks varies, and are usually filled up or grouted with mortar or pieces of brick, or left void, thus forming a species of hollow wall. In diagonal work the bricks lie at opposing angles in the alternate courses. Thus, if fig. 38 be taken as the first diagonal course, the angle or inclination being from left to right, the next diagonal course will have the inclination in the opposite direction, as from right to left. By looking through the sheet or page of paper on which fig. 38 is printed, but with the opposite side of the paper nearest the eye, the arrangement here last indicated will be illustrated. In diagonal brickwork, the first course is that of the ordinary brick bond: thus, if the wall be two bricks (lengths) in thickness, the first course will be two lines of headers placed end to end; in three brickwork, three lines of headers placed in the same way, and in three-and-a-half brickwork three lines of headers end to end.

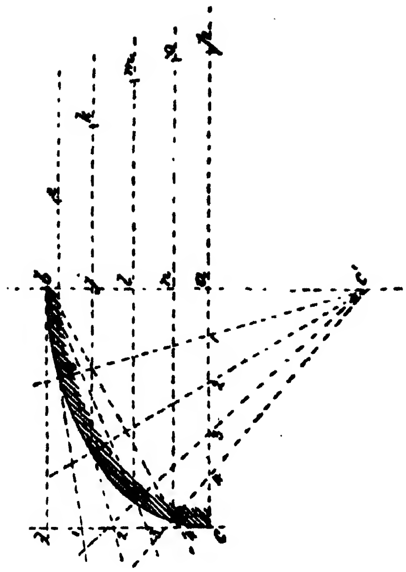
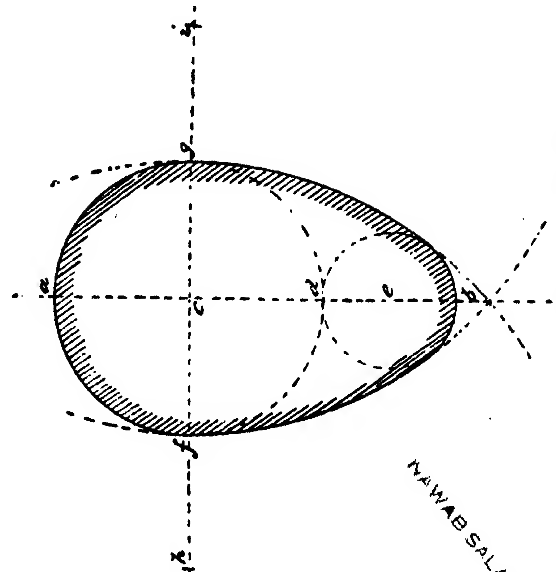


Fig. 2.



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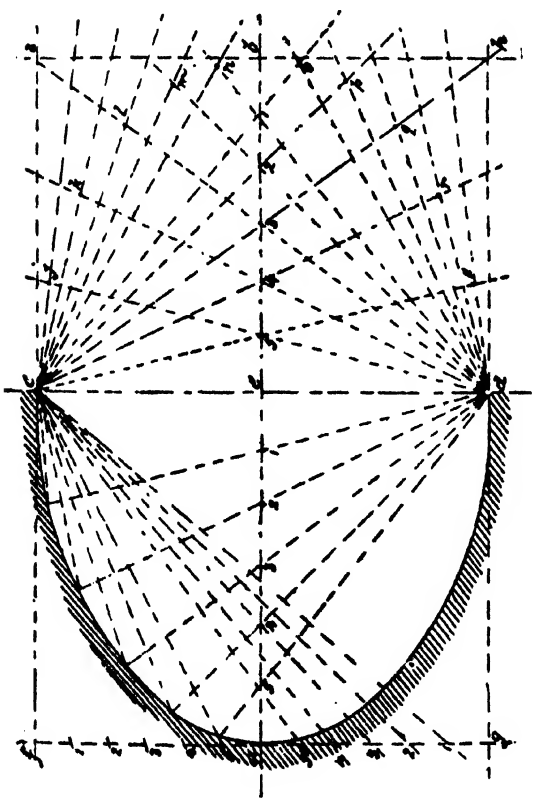

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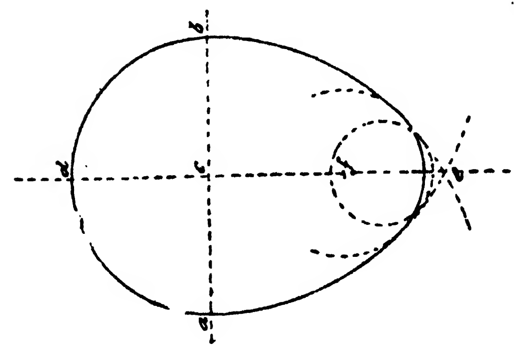

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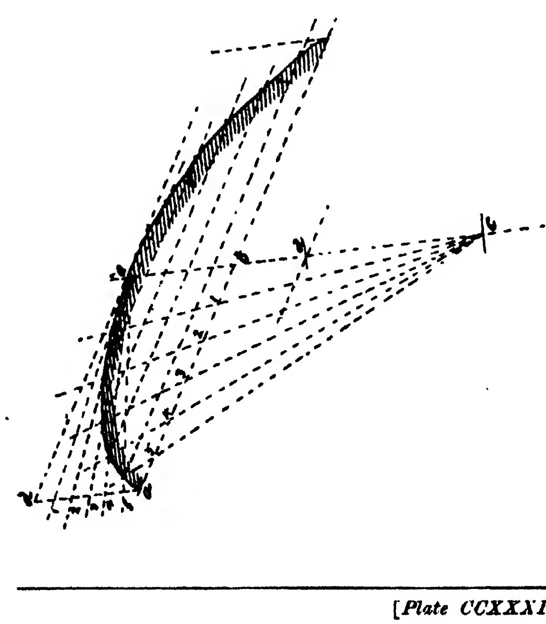

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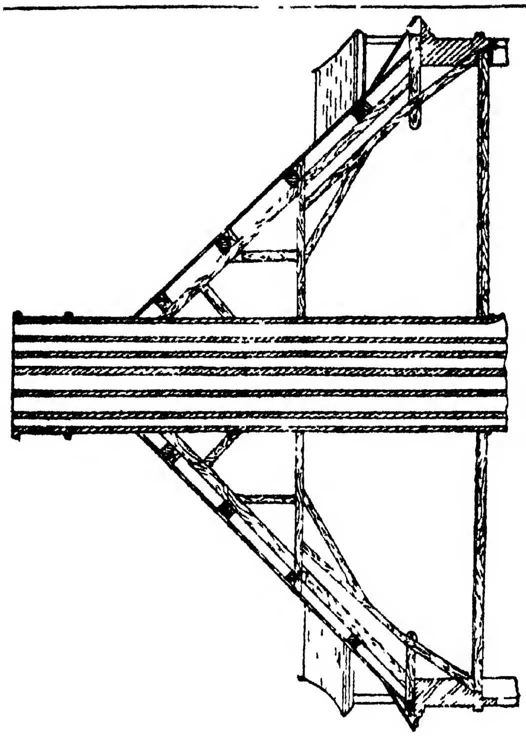
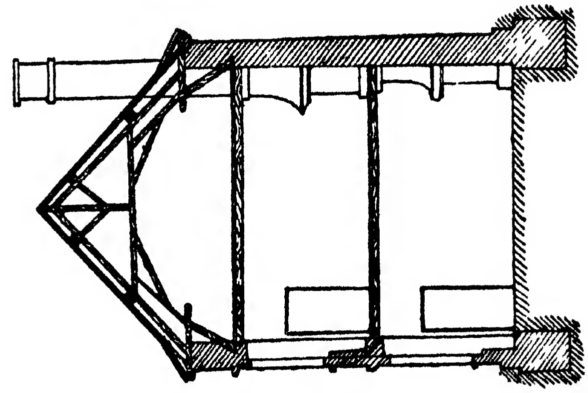


FIG. 2



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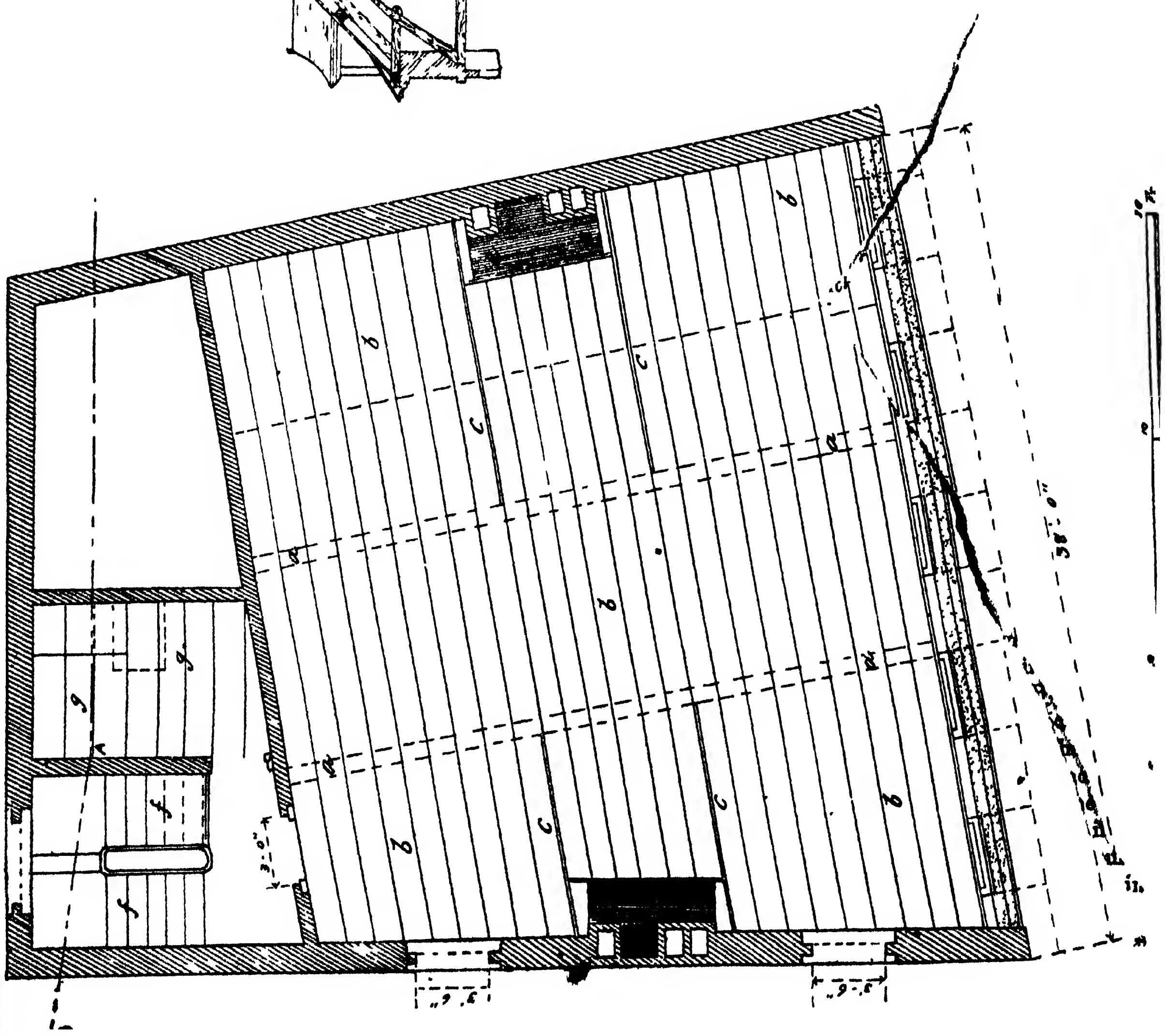

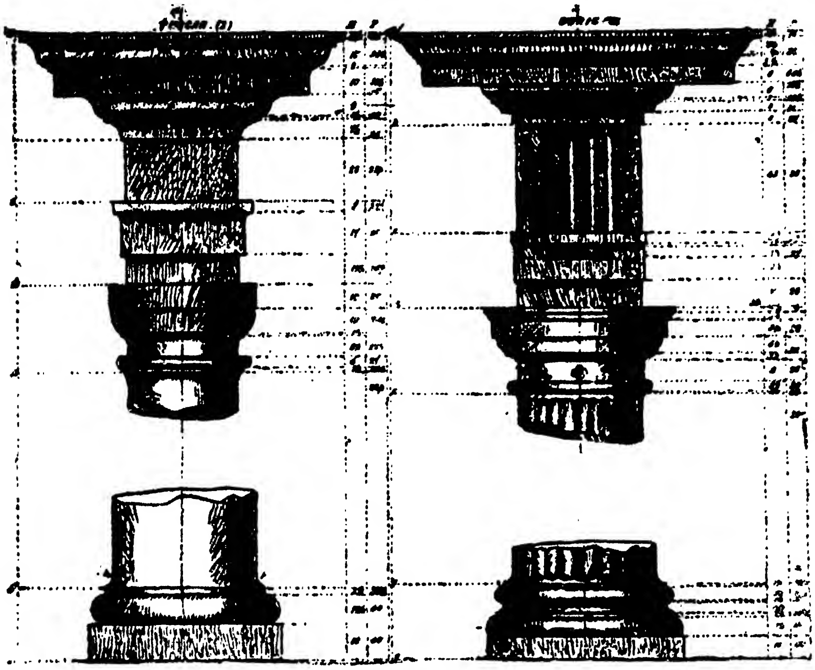

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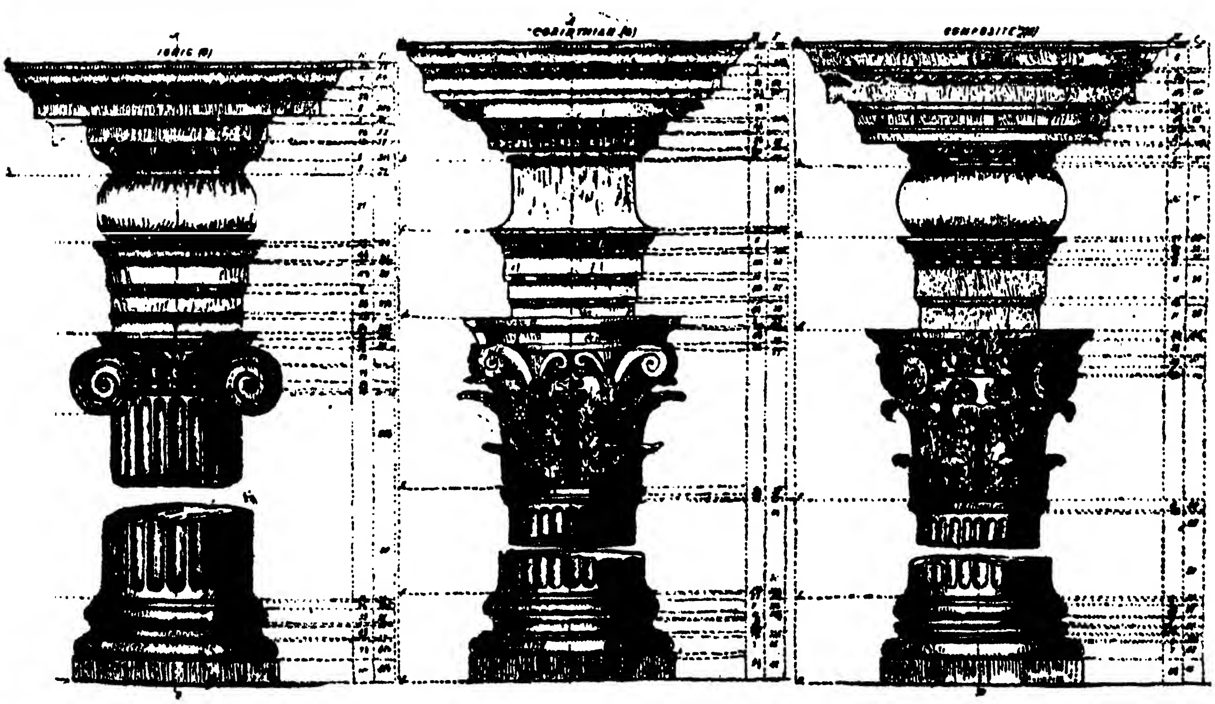
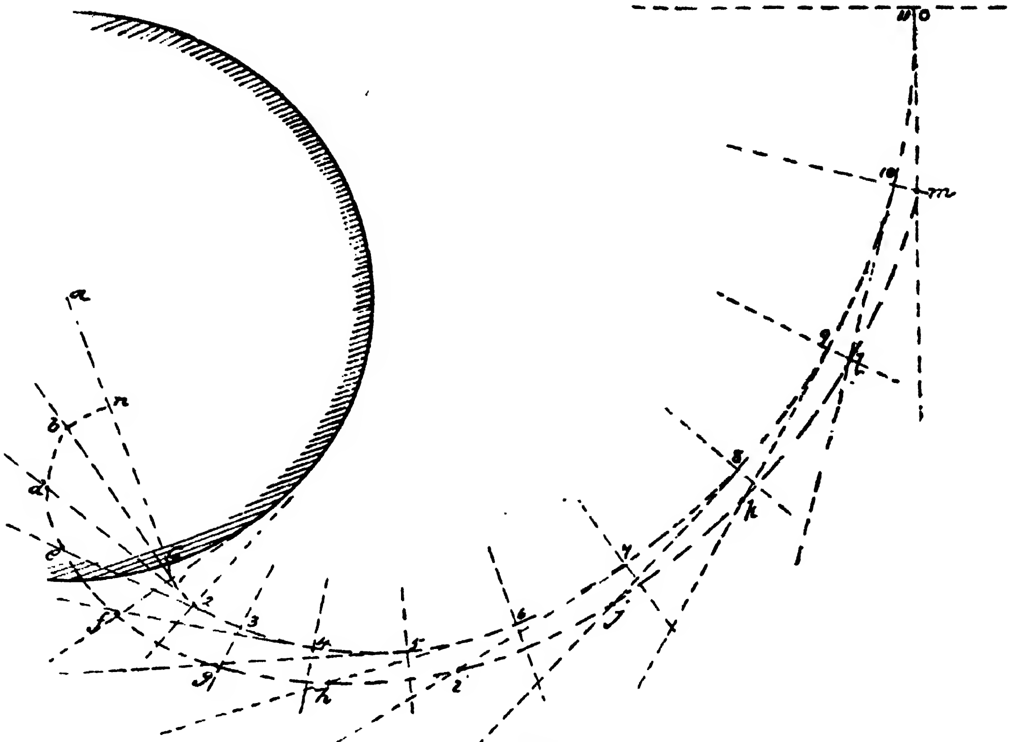


FIG. 3.

FIG. 4.

FIG. 5.



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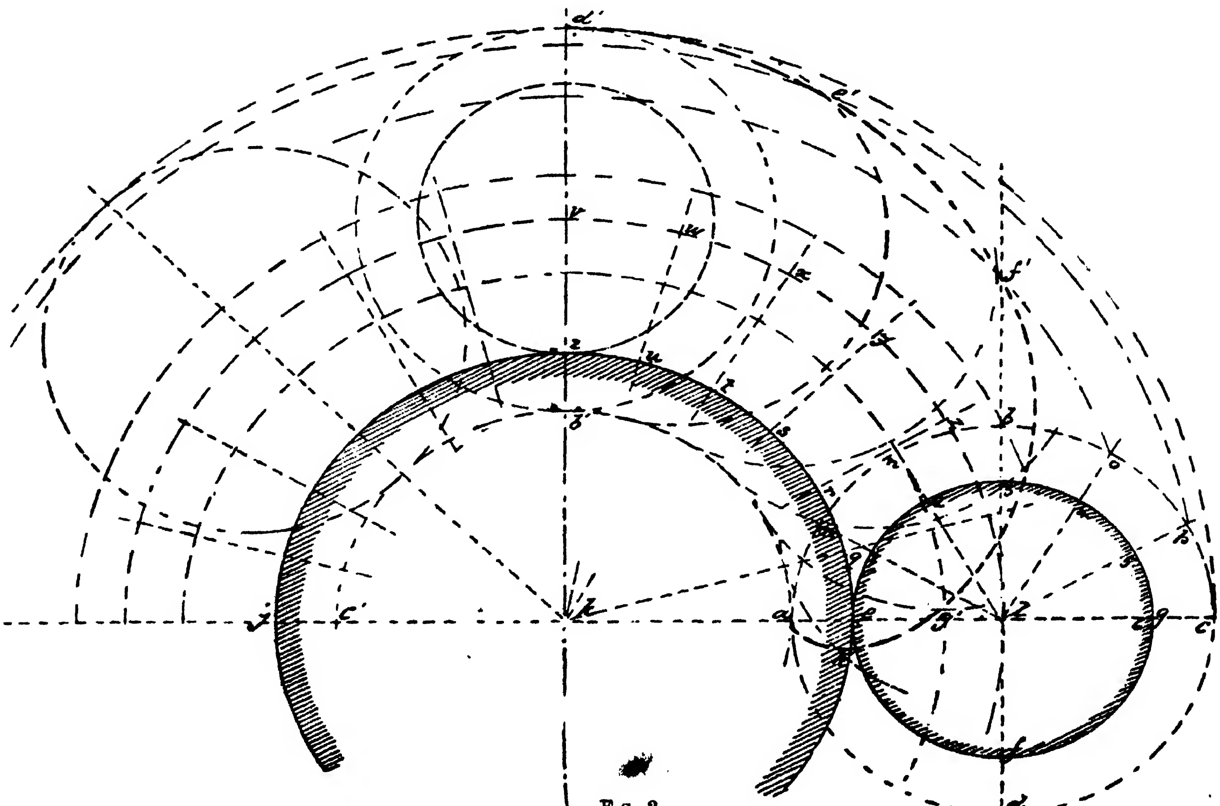
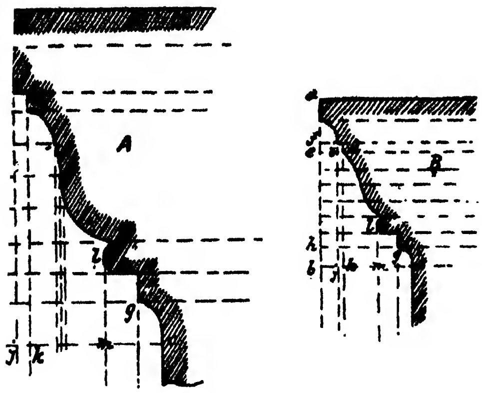


Fig. 2

"MASON AND JOINER," AND "CABINET MAKER."



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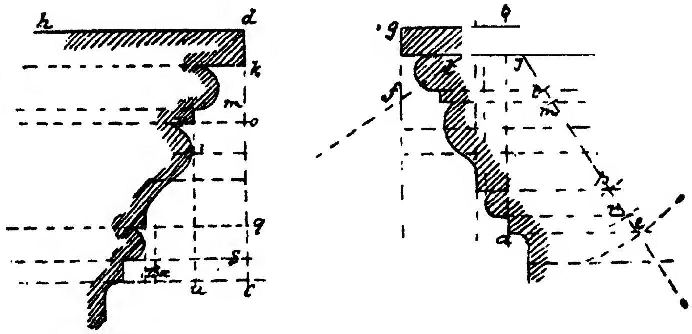

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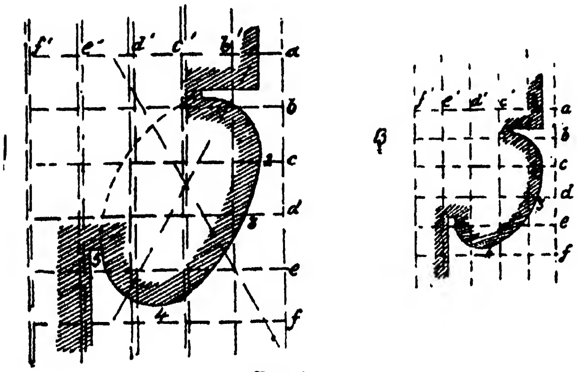

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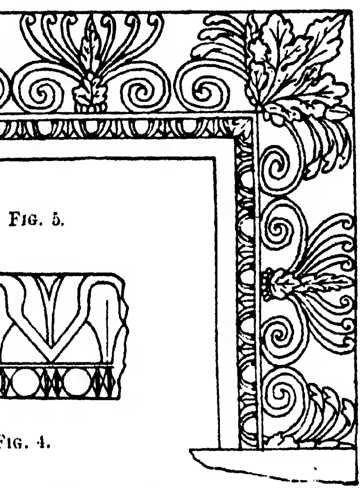

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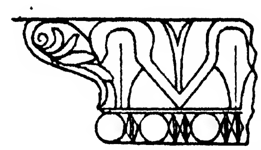

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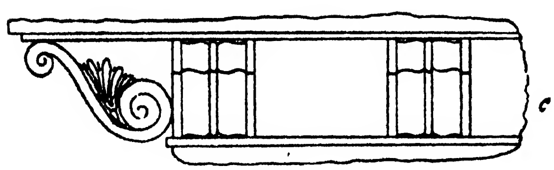

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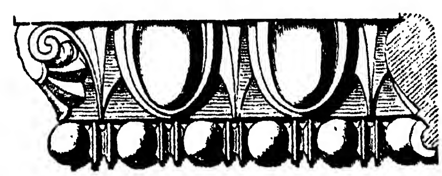

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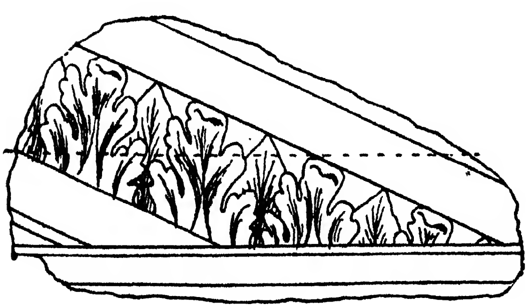

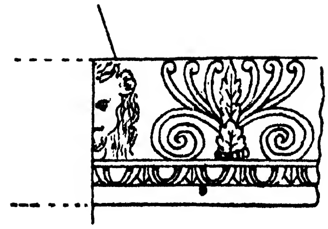

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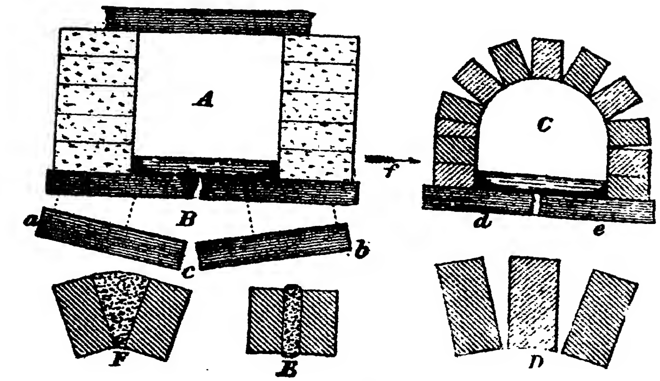

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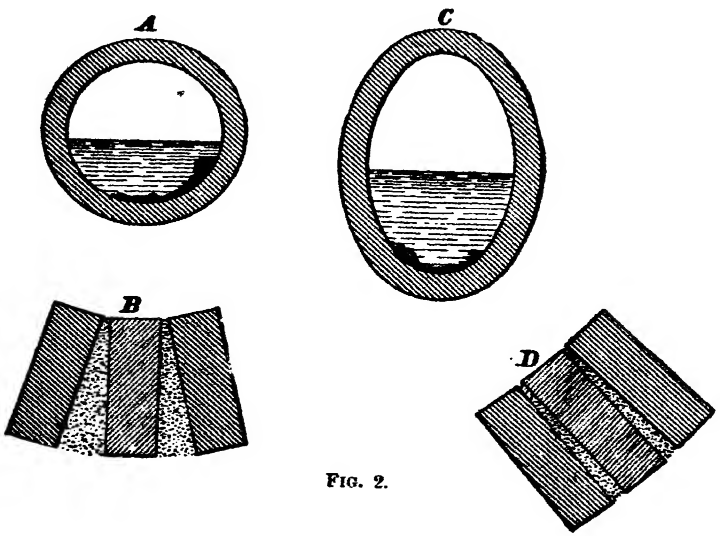

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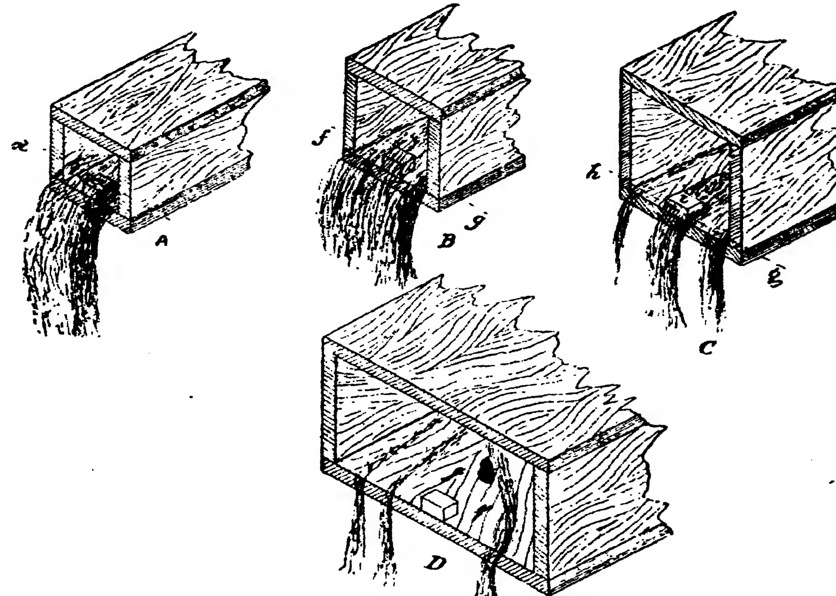

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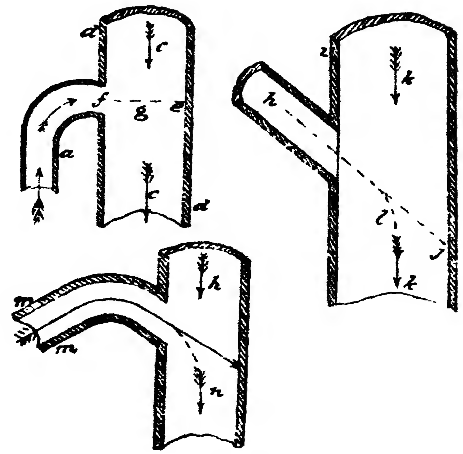
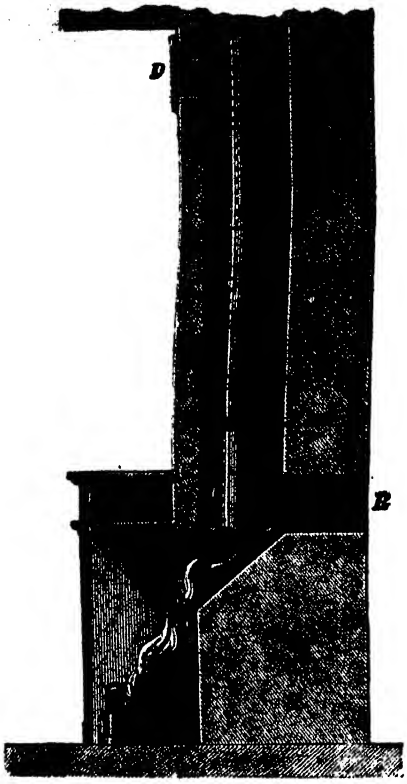


STOVES AND FURNACES.



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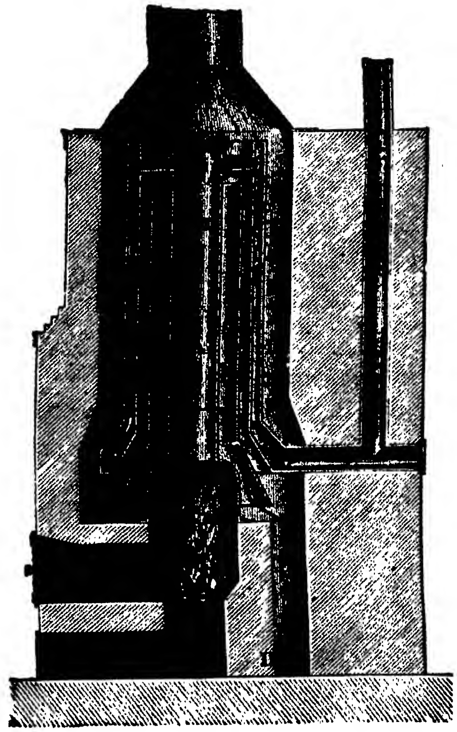

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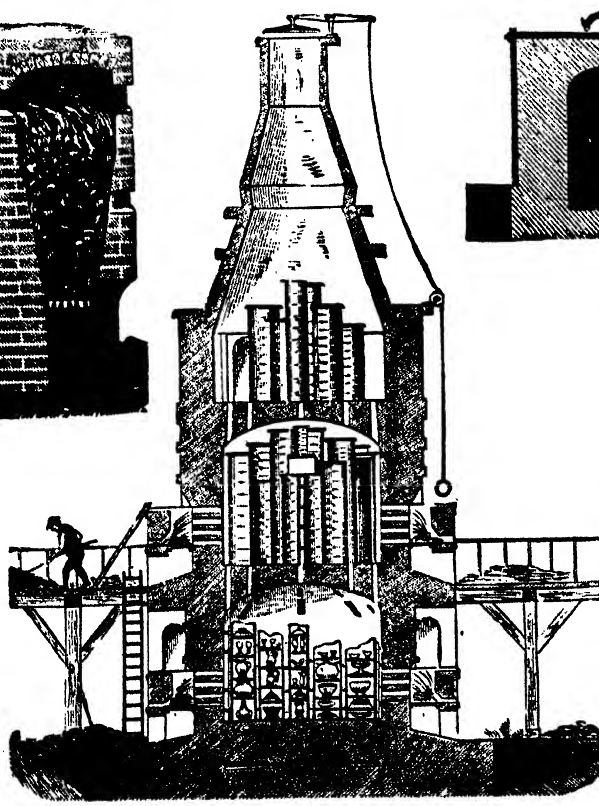

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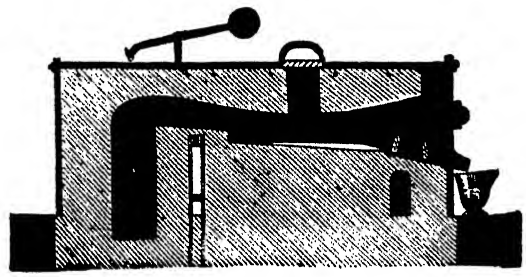


FIG. 5.

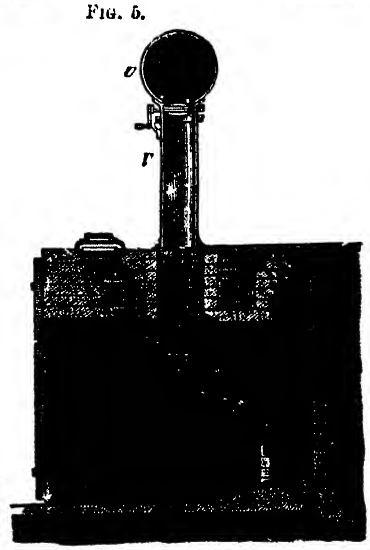


FIG. 6.

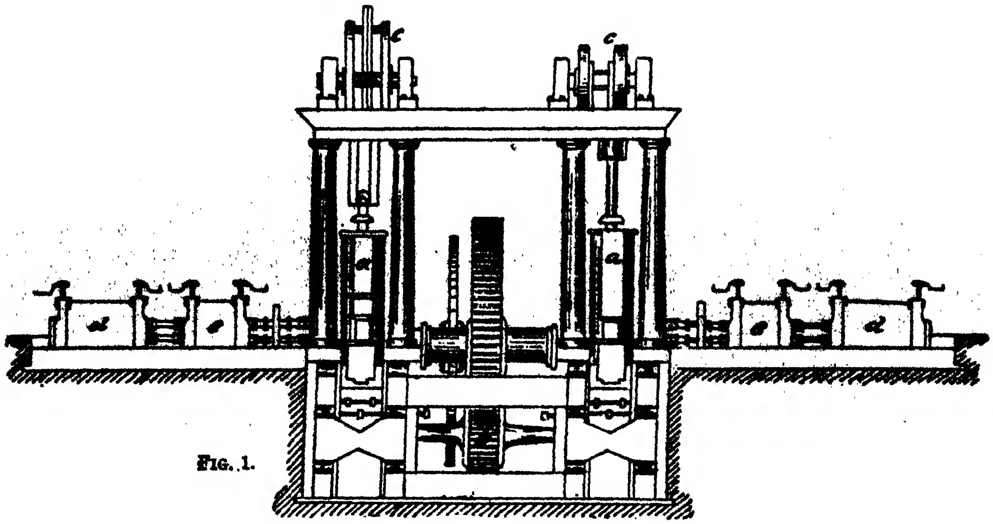


FIG. 1.

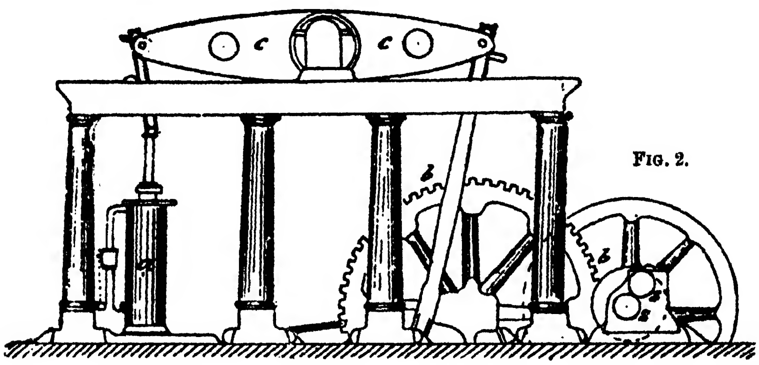


FIG. 2.

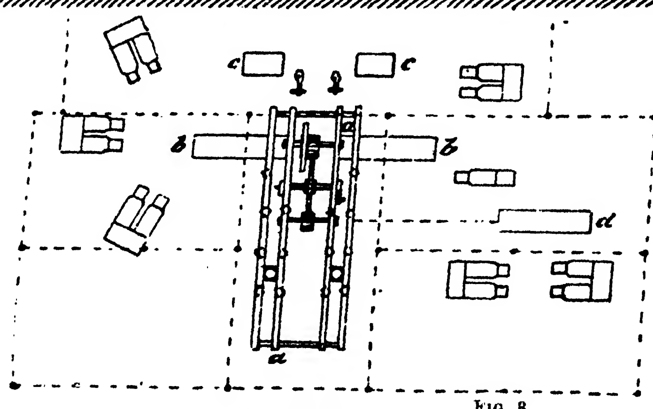


FIG. 3.

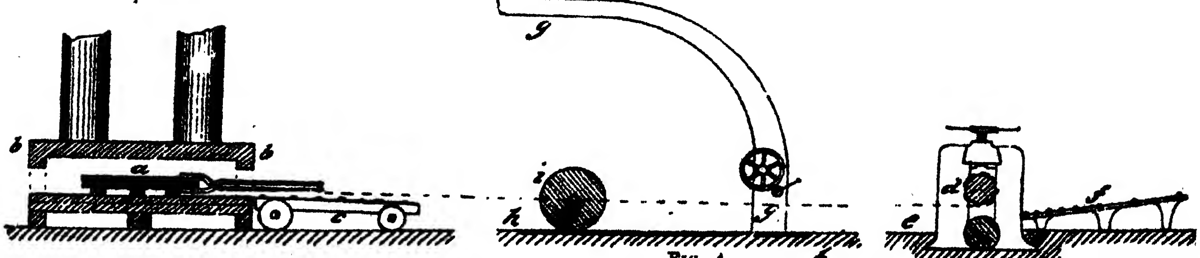


FIG. 4.

THE TECHNICAL STUDENT'S INTRODUCTION TO THE GENERAL PRINCIPLES OF MECHANICS.

LAWS AFFECTING NATURAL PHENOMENA—MATTER AND MOTION.

CHAPTER XXVIII.

Centrifugal and Centripetal Forces (*continued*).

In describing the simple process of projecting a stone from a sling, we have at the conclusion of last chapter explained the two forces brought into action. Those two forces are always existing in all bodies moving in circular directions; and in mechanical work, as it is the centrifugal force which is the most powerful in doing mischief, it is the aim of the mechanist so to arrange his parts that while they have weight or mass enough to give with the velocity of their revolution or circular motion the momentum or force desired, they shall be strong enough to resist the power, so to say, of the centrifugal force generated by the moving body, so as to keep it whole or in good working order.

The Centrifugal Force.

This centrifugal force in heavy bodies moving at high velocities, if not in this way duly provided for, is so powerful in its effects when left free to act, that grave disasters to life and property frequently accrue from this. What a "break-down" is, which is caused by the heavy rim of a fly-wheel becoming fractured and a part or parts of it flying off, many engineers have had costly experience of. The great damage done also by the breaking off of a piece or pieces of a heavy grindstone is due to the fact of the centrifugal force being greater than the "cohesive force," or, to use the more popular expression, of the cohesion of the grindstone, which tends to keep them in contact so as to form a perfect whole. But while forces which he may himself create in order to serve a useful purpose may prove—unless duly provided for and against—to be destructive agencies, those same forces can be, and are, made every day as willing as they are powerful servants to do his varied and ever-varying work. This centrifugal force, so powerfully destructive when acting in a wrong, has, in its useful developments, when controlled in a right direction, been made to do valuable work. We can, of course, find space to name but a few of all the ways in which the machinist avails himself of this centrifugal force to do a variety of work in industrial operations. One of its most simple and direct applications, and which in its varied modifications has been of vast service to numerous branches of industrial work, is met with in the centrifugal drying machine. This, briefly described and illustrated by a mere diagram, consists of a central cylindrical receptacle, hung vertically on a central shaft, which gives it a rotation of great velocity, and surrounded by an outer cylinder, of so much larger diameter as to leave a space, as *a a* (fig. 30), between the two cylinders. The inner cylinder, *b b*, is made with a perforated periphery, making it, as it were, a cylindrical sieve; the wet cloth or other substance from which the superfluous water is to be expelled is placed in the inside of this perforated cylinder, and the whole covered up. Motion is then given to the central shaft at a high speed, and the wet cloth, etc., is, by the centrifugal force generated, driven up—in its efforts to fly from the central shaft—and as it cannot escape to fly off in straight lines, as it would if left free, is, in being carried round with the cylinder, pressed up against its inner surface with such force or power that the water is squeezed out of the folds of the cloth, and passing through the perforations, falls into the free space *a a*. We say falls, but if one could see inside this space, one would find, as the water passed from the inner to the outer face of the revolving cylinder, that it was dashed or thrown off from the outer face in straight lines, and being caught by the surface of the outer cylinder or cover, trickled down to the lower part of the annular space *a a*. Here

Fig. 30.

the "centripetal" force is that exerted or generated by the rapid rotation of the central shaft of the perforated and revolving cylinder, and which is connected to the cylinder by the arms or disc; and here the shaft represents the hand and wrist or arm of the stone slinger,—the arms of the disc which connects the shaft with the outer perforated cylinder the cord or string of the sling,—and the sides or periphery of the perforated cylinder the sling itself. In this machine it is scarcely necessary to state that the inner or perforated cylinder revolves or rotates round its centre or axis; the outer cylinder, which acts as a cover, being stationary. We have had occasion in the preceding paragraphs, and in the present one, to use the words rotation and revolution. As these are what may be called "stock terms" in the vocabulary of the mechanic, in use perpetually, it will be well here, in accordance with the plan of treatment adopted in this work, to show their derivation. In one sense the two terms are synonymous or similar or convertible; in another they are not so. As a rule we associate with the term "rotation"—a circular movement round a central axis—the idea of a slow, or comparatively slow, velocity; with "revolution" a higher velocity.

One would scarcely say that a pulley made an enormous number of "rotations,"—one would almost certainly employ the word "revolutions." The term "rotation" is derived directly from the Latin *rotare*, and this from *rota*, a wheel. So that to rotate is to turn round as a wheel does, and rotation is the act of turning round. Revolve is also derived from the Latin—the two words *re*, again or back, and *volvere*, to roll or turn round. We see, then, that the distinction generally made between the two terms, as above noted, is based upon an accurate conception of the derivation of the two words: thus, rotation conveys the idea that it is movement or motion round a centre, or like a wheel (*rota*, a wheel); revolutions, the number of turns the wheel takes (*volvere*, to turn round).

Increase of Centrifugal Force.

When a body, as a stone carried or suspended in a sling, is swung round in a circle, the cord which connects the sling to the hand is stretched tightly, and has a certain strain exercised upon it, tending to break it. The stone, as it swings round, has an accelerated motion at every deviation from its natural straight line (see preceding paragraphs). The strain or stretch upon the string or cord is a force which is to the weight or mass of the stone as double the free descent or space fallen through, due to the velocity of the mass in falling, is to the radius of the circle which the stone describes as it is swung round. Centrifugal force—or, as in the case of the sling here noted, the strain tending to break the cord—increases as the square of the velocity; and in bodies having a motion of rotation round an axis this velocity is measured by the number of revolutions: the centrifugal force is as the square of the number of revolutions, and simply as the diameter. To obtain increased centrifugal force we can therefore either increase the diameter, or with a less diameter we can increase the speed; and in practice the last will be found generally to be the best expedient. To find the tensile or rupturing strain upon a cord or wire which is fastened to a mass or weight, commence to revolve rapidly, square the velocity in feet per second, multiply this by the weight of the mass, and this by two, divide the product thus obtained by twice the free descent, and this by the length of the wire. Where the speed or velocity of the whirling or revolving stone in the sling in relation to the diameter of the circle which it describes gives a tension equal to gravity, if the sling is swung round in a horizontal path, the stone describes a plane at an angle of 45° with the cord or wire.

Causes of Deviations from the Natural Straight Line of Motion of Moving Bodies.

In connection with the illustrations in figs. 28, 29, 30, and description in last leading paragraph, we have seen that while motion is naturally straight, it is, when acted upon by a force other than the original force, bent out of the straight line, and takes a curved path. In the case of the force of gravitation only acting as the binding force, we have seen that the curve assumed by the body as it approaches the earth's surface is that of a parabola, subject to certain modifications, as in the case of water projected over weirs or through the openings of sluice gates. In the case of bodies moving freely along surfaces under the action of a given force, the form of the curve or the path of motion of the body under the influence of the force is dependent greatly upon certain conditions existing in the body, its form, and the nature of its surface. Some of the phenomena coming under this head present many features of practical interest, and may be usefully glanced at.

In a preceding paragraph we have referred to the influence of what is popularly called "bias" in projectiles, as in the balls used in "bowling." The points opened up by this, affecting many of the mechanical problems connected with "rollers," which play such an important part in a wide range of industrial work, will now be glanced at. Discarding for the present the effects of friction in the cases of bodies rolling along flat surfaces under the influence of a force exerted upon them in a certain direction, a perfect ball or sphere is, so to say, indifferent to the position it may occupy—that is, it will roll along however it may be projected, any point on its surface being at the same distance from its centre as any other point, and the ball or sphere, as $a\ b\ c\ d$ (fig. 31), having its "centre of gravity" also at the true centre, e, of the sphere, this considered merely as a geometrical figure. How the change of its centre of gravity, so that it will not coincide with or be in the same point as the centre of the sphere, affects its relation to a given force, has been already described in discussing the points of "centre of gravity." Apart from friction a perfect sphere or ball will roll freely along a given surface, as $e\ f$, with equal accuracy of motion whether it be "started," so to say, with the point a, for example, uppermost or farthest from the line $c\ f$, or with the point c or any other point.

Form of a Bias in Bodies causing Changes in their Motion.

But if, in place of the ball being a perfect sphere, it is so far "out of the truth"—to use the technical or workshop phrase—that it has at a certain part of its periphery a form different from that of a true sphere, or what is called a "bias" in the language of the bowling green given to it, it will no longer when projected along the surface, as $e\ f$, roll along it in a straight line—deviating neither to the right hand nor to the left—but it will have a curved path, and that in proportion to the amount of its bias or departure from

the surface of a true sphere. Thus, suppose the ball to have a bias at one side, as at *g*, if it be thrown from the hand along a flat surface, as from the point *h*, in the hope that it will reach the point *i*, it will not do so, but will take a curved path and reach some point, as *j*, to the right of *i*. We may further assume that the ball has a double bias, so that it assumes the form shown at *k l m*: if adjusted by the hand of the player and projected with force sufficient—no other disturbing force coming into play—so that the ball rolls upon the part *l l*, it will go in a straight line just as the cylinder *n n* will, as each point in its surface is equidistant from its centre; but the path of the ball will be in a curve, and that either to the right, as *h j* (fig. 31), or to the left as *a b* (fig. 32), according as the ball is adjusted and projected to be acted upon by the bias *l m* or *l k* in fig. 31. And if we suppose that while at rest the body *k l m* remains balanced on the cylindrical part *l l*, so that *k* and *m* are free from the ground, but so nicely balanced that any slight disturbing force, such as that brought into play by some obstacle lying in the path of the moving ball, we can easily suppose that inequalities of the surface, as, say, tufts of grass in the bowling green, will cause the ball at some parts to be rolling on side *l m*, at other parts on side *l k*; and the result of these actions will be that we have a line of motion or a path zigzag, or going alternately to the right hand and the left. Thus, when the ball rolls on bias *l m* (fig. 31), it will move in the curve *c d* (fig. 32), and when an obstacle tilts up the ball so that it now moves on the bias *l k* (fig. 31), the curve will be to the left, as from *d* to *e* (fig. 32). How this change of shape brings about the change of path of motion of a body rolling freely along a level or rather a flat surface, is explained by the diagram at *f j* (fig. 32). In the case of the cylinder at *n n* (fig. 31)—this being of uniform diameter throughout its length—the length of the circumference at end *n n* will be equal to that at end *n' n'*, and when rolling along the ground the length of ground surface gone over by each end will be the same; so that, apart from disturbing influence, the cylinder will roll along in a straight line in the direction of the force acting upon it. But if we trim down the cylinder so as to make the one end much smaller than the other—as the end *u* than the end *n'n'*—we find that this conical roller will no longer roll along in a straight line, but in a curved. The reason for this the youthful student will easily understand from what has been said above; for the diameter of the end *f i* (fig. 32), being so much greater than that at *n n* (fig. 31), the length of surface gone over by it during one revolution of the cone will be just so much the greater than that gone over by the small end *n'n'* (fig. 31). Thus, suppose the circumferential line, during one revolution of this small end, terminates at *h*—the completion of the revolution—the terminal point of the larger circumference of *f i* will be at *j*. The result, therefore, is a curved path, and the curvature or sharpness of this will be in proportion to the incline or angle of the cone. The direction of the curve will be reversed by reversing the cone, as at *l* (fig. 32). And just as we saw in the case of the ball with a double "bias," as *k l m* (fig. 31), so in the case of a double cone we see that when projected from the hand along a level surface with force, it would have a waddling or zigzag line of path, going now to the right, now to the left, according as it was tilted up and its position changed by obstacles meeting it; just as the cone 1 or the cone 2 was made to come in contact with the surface on which the double cone is moved along. In like manner we see that the movements of cylinders, as *n n n' n'* (fig. 31), would be dependent upon the position of the small ends, whether as at *f i h i*, or *l l* (fig. 32).

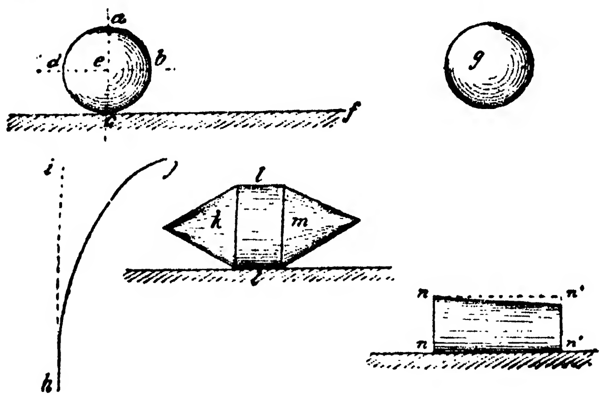


Fig. 31.

Changes in the Direction of Motion of Bodies.

In many of the circumstances of daily life the influence of what is called "bias," in conjunction with centrifugal force, is exemplified in causing changes in the direction of motion. A man in rolling a barrel—which is shaped something like *k l m* in fig. 31—along the ground, can make it take a straight or a curved line of motion, and this latter either to the

right or to the left, simply by making it roll either on the highest part of the barrel, as at *l*, or on the smaller end, *k* or *m*. The change in direction of motion in a rolling body, according to the change in the condition of its rolling surface, is exemplified very clearly in the familiar motions of a coin which has fallen, say, on the floor from the hand of one who has been handling it. The velocity or momentum due to the height from which it has fallen—if it does not fall perfectly on its flat side and remain at rest—sends it off rolling on its edge along the floor. So long as it rolls "truly" on its edge, the eye will see that it takes a straight course. In practice, however, a coin so rolling rolls in a curved line, or more frequently in a series of curved lines in alternate directions; and it is this which makes it so difficult generally to find a dropped coin, as it rolls rapidly aside and goes under some piece of furniture, or rolls in a direction quite contrary to that in which it is supposed to have gone. The reason for the change of direction of motion is that the obstructions on the floor surface cause one side of the coin to be that side, as at point *p* in fig. 32; this imparts to it a tendency to move in that curve; but the tendency of his body, under the influence of centrifugal force, being to move in a straight line, the body does not follow in the curve quickly enough, and the result of the two tendencies is to throw the body once more into the perpendicular, and he is thus saved from falling. It is precisely this principle which keeps a hoop with a narrow rolling edge when rolling from falling on its side—supposing the impelling or propelling force is sufficient to give it motion. So soon as an obstacle on the ground causes it to tilt up to one side, and to run therefore on one edge, as at *p*, the tendency to sweep off in a curve towards the right hand being met by the centrifugal tendency to go in a straight line, brings the hoop to run on its flat edge, as at *o* —or the central point, *r*, if the rim be round—and thus assume the perpendicular. These influences, in the course of a long motion, may be repeated again in operation; they are always ready to act, and the hoop, so to say, goes through them intuitively, just as

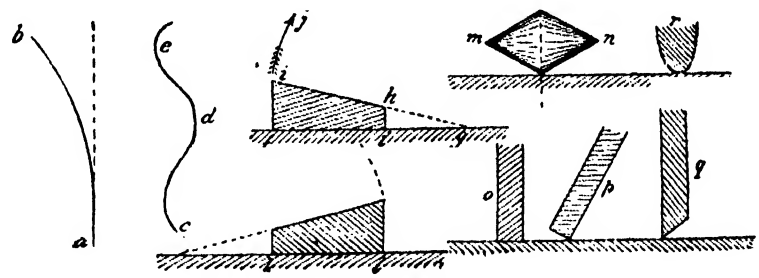


Fig. 32.

tilted up, so that from rolling on its rim, as at *o* in fig. 32, it assumes the position, say, as at *p*, and, running on its edge, it describes a line which, although in reality forming a spiral, carries it on in a curved line to the right, till another obstruction causes it to tilt over to the left, as at *q*, when, rolling on its opposite edge, it rolls towards the left. The student should think out those three positions in relation to the force which causes the coin to roll. A beautiful exemplification of the influence of bias or change of position of a body moving swiftly over a surface is met with in the practice of the skater, in enabling him to describe an infinite variety of curves on the ice in his career; and this he does by simply changing the relation of the sole or flat edge, *o*, of his skate, as at *p* and *q* in fig. 32. By changes also in this way he keeps himself from falling; for, just as a man on a horse, in turning a sharp corner swiftly, gives bearing or "bias" *towards* the corner, in like manner, if the skater finds that he is likely to fall towards, say, the right hand, he gives his skate a "set" towards the skater does. But perhaps the most familiar illustration now-a-days of the principle here explained, in which these tendencies are made available in preventing falling, is met with in the case of the "bicycle," the conditions of motion of which the student should think over. The performer in a circus, on feeling that he and his horse have, in their intuitive desire to correct the influence of centrifugal force, given too much bias, and that they have a tendency to fall inwards, increases the speed of his horse, and thus gives the desired tendency to rise up from the angle or inclination to falling—the converse work of reducing the speed of his horse being gone through if he feels a tendency to fall outwards or from the centre of the ring. All this is done by the practised circus performer, and so also by the bicyclist, whose performances create such surprise to those who are not acquainted with the actual laws upon which his performance depends. There are in connection with bicycling many curious mechanical points, which the student will do well to consider.

THE STEEL MAKER.

THE DETAILS OF HIS WORK—THE PRINCIPLES OF ITS PROCESSES—THE QUALITIES AND CHARACTERISTICS OF ITS PRODUCTS.

CHAPTER XII.

IN continuation of the subject of the process of steel making on the Bessemer system, which was begun in preceding chapter, the inventor proceeds: "Instead of tilting the casting ladle for pouring into the moulds, it is made with a hole in the bottom fitted with a fireclay seating, *l*, fig. 6, and closed by a conical plug of fireclay, *m*, forming a conical valve. The valve rod *n* is coated with loam and bent over at the top, and works in guides on the outside of the ladle, with a handle, *o*, for opening and closing the valve. By thus tapping the metal from below, no floating scoria or other floating impurities are allowed to run into the mould, and the stream of fluid steel is dropped straight down the centre of the mould right to the bottom, without coming in contact with the sides of the mould. The moulds are made of a slightly tapered form, as shown in fig. 6 at *k k*, so

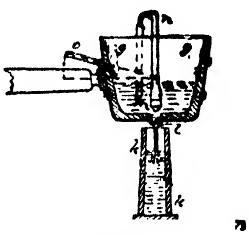


Fig. 6.

that, as the ingot contracts in cooling, it liberates itself from the mould completely on all sides; and the mould is removed by being lifted off the ingot when sufficiently set. The moulds are arranged in the moulding pit in an arc of the circle described by the casting ladle *g*, fig. 3. By this process from one to ten tons of crude iron may be converted into cast steel in thirty minutes, without employing any fuel except that required for melting the pig iron and for the preliminary heating of the converting vessel, the process being effected entirely without manipulation. The loss on the weight of crude iron is from 14 to 18 per cent. with English iron worked in small quantities; but the result of working with a purer iron in Sweden has been carefully noted for two consecutive weeks, and the loss on the weight of fluid iron tapped from the blast furnace was ascertained to be only 8¾ per cent."

Since the above was written, vast improvements in the manufacture of steel have been made, to such an extent that the process of actual making may be said to be quite a new one; but the above gives a very clear exposition of the general process, and that from the pen of the inventor of the himself.

Early Improvements in the Bessemer Steel Making Process.

We have already said that so complete a grasp had Sir Henry Bessemer taken of the system of working out his process of steel making, and of the mechanical necessities which this demanded, that the arrangements he devised for the works fitted up at an early period in the history of the invention, and of which the preceding description and illustration afford an excellent example, are almost identically the arrangements of the present day. The converter, the tipping contrivance, the hydraulic crane and ladle—indeed, as we have just said, the whole arrangements—although they have received modifications and improvements in detail, remain in works of the present day the same in all essential features as in those works erected or fitted up with the apparatus some twenty-three years ago, that being the extent of the interval which has elapsed between the date at which we write and that of the publication of the paper by Sir Henry Bessemer of which we have given the principal matter in the preceding paragraph and illustrated by figs. 1 to 6 inclusive. It is not to every invention that the high praise involved in the above statement can be accorded. The improvements which have been made have consisted chiefly in more economical methods of working the process generally. We now proceed to notice those improvements which have made the process one not merely more economically, but much more quickly and directly carried out, than it was at the earlier period we have just alluded to. At the end of the preceding paragraph a reference is made to the "reverberatory furnace" as forming in its use part of the then method of carrying out the Bessemer process. This furnace formed, in fact, a most essential part of it, it being then considered necessary to *re-melt* in a special furnace the cast iron, the original product of the large or ordinary blast furnaces. It is right to state that in his original conception of the process Sir Henry Bessemer designed to operate at once on the cast iron as it was produced in the blast furnace—without the intervention of any re-melting or heating furnace. That this plan was not from the first adopted arose from a variety of circumstances, amongst which was doubtless the impurities of the cast iron, arising from the debased character of the ores employed, containing, as so many did, and still unfortunately do, so large a percentage of the chief debasing elements, phosphorus and sulphur. Whatever the cause which made what we may call the roundabout system of working, in which the cast-iron was first taken from the blast furnace, then re-melted in the reverberatory furnace, and finally passed through the converter, it was for long considered absolutely essential that this should be the process by which Bessemer steel was to be produced. And for long, greatly to the increase

of the cost of the new metal—for the re-melting occasioned, as we shall presently see, a large consumption of fuel, to say nothing of the original cost of the furnaces and their maintenance in working order and efficiency—the roundabout or indirect process was carried out. No one for a long time seemed to think that it was other than necessary, or that it was worth while to put the notion to the actual test of practice that it might be dispensed with, and a more if not an absolutely direct process substituted.

We have a parallel case to this condition of things in the invention of railways and railway locomotives. For a long time it was considered to be a fact that there was so little adhesion or "grip" between the surface of the rails and that of the periphery or tyre of the driving wheel, that unless special means were taken to make or increase the grip, the power of the engine would be merely expended in causing the driving wheels to revolve without causing the machine with its attendant load of carriages to progress along the rails. To overcome the fancied difficulty no end of ingenious mechanical contrivances were brought out, and several patented, amongst which we may name the curious arrangement of Blenkinsop, by which the leg motion of a horse was imitated in a way almost comical in its conception, ingenious as were the means by which it was realised. The mind even of such a thoroughly practical man as George Stephenson—the true father of the railway system—was so dominated by this fanciful notion that he entered the list of inventors who brought out contrivances by which the fancied difficulty was to be overcome. The history of mechanical improvement has not recorded the name of the bold mechanic who first conceived that this "difficulty" of the early locomotive makers was in reality a fancy or mere belief taken up and maintained without any reference to facts as they were; nor does it record the time or period in the progress of railway invention when this individual, whoever he was, boldly put the point to the test of practice, and showed beyond a doubt that the difficulty was in reality a mere fancy. All that we know is that the "difficulty" suddenly ceased to be considered as one really existing, and the progress of the locomotive to its present state of nearly absolute perfection was secured.

In this question of the Bessemer steel making, history is not so silent as to him who first questioned the correctness of the fact, maintained by all to be one, that the "re-melting" was a necessity of the process. It does not, however, say precisely who this was, for there are two claimants for the honour of the discovery: one Mr. George Brown, a member of the well-known steel making firm of Sir John Brown and Co., of Sheffield; the other Mr. John Bird, of the Railway Steel and Plant Co., of Newton Heath, near Manchester. This latter gentleman was, if not the first in the field with the new idea that there was no necessity to employ the roundabout system of re-melting, but that steel could be made by the converter from cast iron taken directly to it from a blast furnace, certainly, so far as evidence goes, the first publicly to announce its successful adoption, in a special paper read so early as 1868 before a meeting of the "Association of the Employers, Foremen, and Draughtsmen of the Mechanical Trades." The point involved is one of special importance in the history of the trade, inasmuch as it succeeded in effecting so large a saving of time and money in individual cases that, taken in the aggregate, it amounted to an enormous sum, increasing in proportion daily as the Bessemer process itself increased; and it conveys also a practically suggestive lesson to the mechanical student.

Working the Bessemer Converter with Cast Iron taken directly from the Blast Furnace.

The substitution, in this plan of working, of the blast cupola for the air-draught reverberatory furnace, formed an important step in the progress of the Bessemer steel making process, and opened up quite an extended area for its working, inasmuch as it saved a large and, as we have said, a useless expenditure, from much of the metal being lost by the reverberatory furnace, and sometimes, as we have seen, causing a direct loss of the whole, or nearly the whole, of the re-melting. But great an improvement in the working of the Bessemer steel making process as the introduction of the cupola was, another step in the direction of simplifying its details was yet to be made; and this was in the working of the process in a positively direct manner by doing away with the use even of the cupola, and by taking the cast iron directly from the ordinary blast furnace and carrying it in a molten state to the converter, where the process of conversion into steel is at once gone through with and completed. Here we have the simplification of the process carried out to its fullest extent, for there is nothing intervening between the blast furnace, in which the cast iron or "pig" is produced from the crude ore, and the converter by which it is changed or "converted" into the steel known as Bessemer steel. This simplest of all methods of working the Bessemer process is obviously, however, dependent upon either the good quality of the "pig," produced from ores comparatively pure—that is, free from the most active of the debasing elements, phosphorus and sulphur—or upon some mixtures which will give as the produce of the blast furnace a "pig" which, when taken from the blast furnace and led or taken direct to the converter, will be of that quality which will enable the process to be carried out efficiently in the production of good

steel. We shall presently see how this essential element in the working of the "direct" method of working the Bessemer process is effected. Meanwhile it is noteworthy that, although we have stated that this direct process carries the Bessemer system to its utmost limit of simplification, this is only comparative, not absolute. For the production of steel, even in this process of working, is only so far indirect or roundabout that there is still rendered necessary the use of the blast furnace—which is the oldest but one of the iron manufacturing appliances—before the iron or "pig" can be produced upon which the converter is to operate. The true limit of simplification obviously lies in the direction of that process, yet to be discovered, by which the "converter" or some other form of vessel or appliance which may be necessitated by the new discovery, will take up and deal with the crude ores themselves, and at one operation change those or "convert" them at a commercial profit on the large or working scale into steel.

Making of Steel direct from the Iron Ore.

This process of making steel direct from the ores has been the dream of many for a long period; and what has been done to realise it we have in a preceding chapter briefly glanced at. As yet the matter is but a dream; although, when we know that such a man as Dr. Siemens was hard at work for years upon the solution of the problem, it is not too much to hope that the dream will before long be realised, and the conversion of the crude ores into steels of various qualities—from the lowest, which may be classed only as the finest quality of wrought iron, up to the highest qualities of steel, capable of making cutting instruments of the highest efficiency—become a practical fact, forming one of our regular trades. No doubt the possibility of this being yet done seems to many so unlikely that they in reality look upon the notion as in every sense the outcome of a "dreamer's mind." But there has been surely enough done of late years, not in the wide field of general science, but in the comparatively limited one of metallurgy alone, to make one pause before so dogmatically deciding that a conception, or dream, or whatever he chooses to call it, cannot be realised in practice. The very subject we are now considering gives us the caution needed, to be guarded in our being so positively certain that this much-to-be-hoped-for realisation of the dream of not a few of our ablest metallurgists is a thing which is impossible. For there were those who sneered at the notion that the reverberatory furnace was not indispensably necessary to the Bessemer process. Mr. Birch has, indeed, told us that he had to practise a species of innocent deception before he ventured publicly to expound his simple method of working, by which the reverberatory furnace, with all its inherent faults and consequent losses in time and material, was done away with by the introduction of the cupola. And, doubtless, when the cupola had been established, and become itself a "thing to stand or swear by," as the one thing which must be preserved, as had been the reverberatory furnace in its day of supremacy, those who suggested that even it might be dispensed with were looked upon as only dreamers. The direct process of making steel at once from the iron ore — truly deserving the name — may yet, therefore, some day be ushered into the world of the iron trade; and if, in addition to its capability of producing good steel from good ores, it can deal also with those which are debased, we shall then, indeed, see the manufacture of steel reduced to its simplest possible elements.

Bessemer Pig Iron.—The Cast Iron specially adapted for the Bessemer Process.

We have said that one of the causes which led to the consideration that the roundabout process of re-melting the cast iron in special cupolas was necessary, was the impurities of the cast iron employed in the process and those arising from the debased ores used, the debasing elements or constituents being chiefly phosphorus and sulphur. In tracing the history of the Bessemer process, we have seen that the process did not, as Sir Henry thought it would, completely eliminate or get rid of the phosphorus and sulphur present in the cast iron he proposed to change or "convert" into steel,—and this chiefly by the enormous degree of heat which the process created. On the contrary, so far from this being the result of the process, Sir Henry Bessemer was so beset with difficulties arising from the presence of these debasing elements of phosphorus and sulphur in the metal he dealt with, and so impossible was it to get rid of them, that at one period the process was very nearly wrecked, and seemed doomed to be set aside as practically impossible, correct as was the theory upon which it was based. And had it not been for the discovery of ores then, of the celebrated "Cleator" in Westmoreland, which were singularly free from phosphorus and sulphur, and which lent themselves so aptly to the Bessemer process that the "pig" made from them became known as "Bessemer pig" iron, it now seems beyond a doubt that the process would have been a failure in place of the brilliant success we all know it to be now. Later still came the Thomas-Gilchrist process of iron treatment, as adapted to the modern systems of making steel either on the Bessemer "converter" or the Siemens "open hearth" principle. This process seems to open up the positive prospect of even very debased ores being made available for the making of steel on one or other of the systems named above.

THE IRON MAKER:

THE DETAILS OF HIS WORK AND THE PRINCIPLES OF ITS PROCESSES.

CHAPTER XII.

Working Plant of the Cast Iron Manufacture.—Working of the Blast Furnace.—Hot Blast Furnaces (*continued*).

REFERRING to what was said in preceding chapter under this title, we have to point out that the blast furnaces, as we have already said, are usually worked in pairs—so that one hoist will serve the two—although there may be more pairs than one. In gigantic establishments such as that of the celebrated works of Messrs. Bolckow, Vaughan, & Co., of Essen, near Middlesbrough, the blast furnaces are so numerous that, placed in lines or rows, they may be said to form streets of furnaces, the first view of which must always impress the spectator with a very vivid conception of the industrial power and resources of our country. Immediately behind the two furnaces, as *h h*, in fig. 2, Plate CLXVII., there are two other furnaces constructed at the points *d d*. The office which these have to fulfil is the raising of the blast of air at the ordinary temperature, which is created by the blowing engine, up to the high temperature which distinguishes what is called the "hot blast," a term used to denote the fact that the air sent into the furnace is not—as used to be universally the case at one period in the history of the iron manufacture—sent or blown into the furnace at the ordinary temperature of the air, but that it is heated to a degree far in excess of this. The hot blast, or rather the highly heated air which the hot-blast system demands, is created in the large volume required for the reduction of the ore by the employment of one or other of two forms of furnace or heating apparatus. These two are known as the ordinary "hot-blast furnace" and the "gas heated furnace," or one or other of the modifications of the well-known regenerative furnace.

The current of air is forced through the iron pipes which constitute the heating surfaces of the ordinary hot-blast furnace or stove—as it is very frequently termed—or through the air-spaces of the gas or regenerative stove or furnace if this system be adopted, by the power of the blowing engine. This is placed in the engine-house, the position of which is marked at *f*, in fig. 2, Plate CLXVII., close to the boiler-house in which the boilers are placed by which the supply of steam required by the blowing engines is produced. The air is passed from the blowing engine in engine house at *f*, through a large-diametered iron pipe *e e*, termed the "cold-blast main," as the air passing through it is at the temperature of the ordinary atmosphere at the time being; it is then delivered to and passes through the heating surfaces of the furnaces situated at *d d*; and after being highly heated—from 500° up to as high as 1500° and above—is passed to another range of iron pipes, but lined with fire-brick to protect the iron and to maintain the heat as near as possible to its initial temperature as produced by the stove or furnace. This range of tubes is termed the "hot-air main," shown at *g g*, in fig. 2, and communicating directly with the *tuyères* of the blast furnace at *h h*.

On the reduction or smelting of the ore being completed, the resulting fluid iron is withdrawn from the blast furnace and is run into channels or moulds, the main channels being, as we have in a preceding chapter seen, termed "sows," the tributaries or minor channels, which are in fact the "moulds" which give forms to the masses of metal, we have seen to be called "pigs" or pig iron. These moulds are made in sand, which forms the floor of what is called the "pig bed," indicated at *j j* in fig. 2, Plate CLXVII. This pig bed in large establishments has a large area—in some instances having a sufficient surface to give a very large number of moulds. The "slag" or glass-like silicates, described in a former chapter, is run into slag boxes of dimensions sufficient to contain some two or three tons of slag. These are taken away by the slag rails indicated at *k k* in fig. 2, Plate CLXVII., communicating with or forming, as it were, "sidings" to the main line of working rails, *l l*, of our establishment. To work the slag boxes small locomotives are used.

In referring to the diagram in fig. 3, Plate CLXVII., the reader will perceive that, connected with the upper parts of each of the two blast furnaces, *h*, *h*, is a pipe or tube marked *n n*, leading to the ground level. These pipes or tubes are called the "down-comers," and their office is to carry off the "waste gases," or by far the greatest bulk or volume of them, from the upper part of the blast furnace to a brick-lined main or culvert placed underground. This leads to the boiler-house, *f*, in fig. 2, Plate CLXVII., on the one hand, and to the hot-blast stoves *d*, *d*, on the other. The "waste gases" are largely composed of carbonic oxide gas, which is inflammable or combustible, as we have in a preceding chapter explained in connection with the action of the blast furnace. The waste gases thus taken to the boiler house *f*, and used for hot-blast purposes at the furnaces *d*, *d*, are by certain simple arrangements flashed into flame, which, travelling along the boiler or hot-blast furnaces, raises the steam or the temperature of the air, as the case may be.

Utilisation of Waste Gases of the Blast Furnaces.

At one—and that by no means a remote—period in the history of the iron manufacture, these waste gases were in every way deserving of the name, inasmuch as no attempt was made to utilise them in any way; although it must have long been obvious to iron masters that an enormous current or volume of heat was poured into the atmosphere through their

means. And although the heat required for the regular work of the reduction or smelting was costly to a degree in its production—the whole of the plant being practically required for it—still no one for long seemed to think that in the vast volumes of heated gases sent into the air at the top of the blast furnace, there might lie some source of supply of heat which might be useful in the works below; and in whatever proportion so used would tend to reduce the cost of producing the supply of heat by which the process of reduction or smelting could be carried on.

Although now largely, practically in the English iron making establishments universally used, these gases are still, in the technical language of the trade, termed "waste"; and the term is in one sense strictly applicable, inasmuch as they are, in relation to the process of reduction or smelting, one of the products of that process which has no direct value in connection with the iron. A better term is now, however, being used in relation to the so-called waste products of any industrial process, this being the "bye-products"; and the great improvement witnessed in all our industrial work is perhaps in no way more strikingly exemplified than in the fact that uses, and valuable uses, are found for many of those "bye-products" which at one time possessed no apparent utility, so that they got, and deserved, the name of "waste products." The merit of being the first to take steps towards the utilising of the waste gases of the blast furnace is keenly disputed by the iron trades of France and of England. Whether or not it be the fact that the first application of a proposal to apply those waste gases to a useful purpose was made in England, we do not now inquire into; but this fact remains, and we believe is undisputed, that more than one iron master in France used, and with marked success and economy, the waste gases of his blast furnaces during a period in which our iron masters not only refrained from using them, but insisted upon the fact that they were not usable at all, that nothing could be made of them in a practically useful way. It was long after the system of using those waste gases of the blast furnaces in the production of heat, chiefly for steam-raising purposes, had been introduced with success into France, that our iron masters became convinced that in them there really lay a store of heat which, if availed of, would effect a large economy in the consumption of the coal or coke which was required in such enormous bulk at our large iron works. Some idea of this economy may be obtained when we state that in the majority of our establishments the steam required for the various engines, especially for the blowing engines, is raised wholly by the employment of the waste gases; and not only this, but they are employed in the production of the hot blast. And some idea of the heat sources which for so many years had been completely lost to the trade, under the old system of blowing them out at the furnace throat uselessly into the atmosphere—creating an evil, moreover, by contaminating this—may be obtained when we state that, after using the waste gases for the raising of all the steam required in the works, and of the hot air required for the blast furnace, there is generally a surplus, and in many cases a large surplus, of heat from the waste gases left over, for which some use may yet one day be found.

An idea of the costly character of the plant of iron works will be gathered from the statement that to erect two blast furnaces of a cubical capacity each of over thirty thousand feet, some sixty thousand pounds will be expended. The expense weekly in the matter of men required to work the plant is large, over seventy hands being required, of whom one-third of their number take the "night shift," two-thirds taking the "day shift." The capability for work possessed by one of those large blast furnaces may be gathered from the fact that it produces some, and in many cases over, 500 tons of pig-iron every week.

The Supply of Air at Pressure to the Blast Furnaces.—The Blowing Engines.

We have in the preceding paragraphs described in a general way the various departments of the "plant" or working structures and appliances required in iron works on a large scale. We now proceed to notice in greater or less detail the various sections of this plant. And we begin this part of our work with the means for producing the blast of air, which is the first essential element in the practical working of the blast furnace in reducing the ore. To give even the briefest *résumé* of the historical and practical details of the blowing engine, by which the blast is produced, would absorb an amount of space far exceeding our limits. So wide, indeed, is the subject, so interesting in its historical and so important in its practical aspects, so numerous have been the forms of blowing engines introduced, so extensive is the list of improvements in their minor details even, that it would take a large volume to do justice to the subject, and a large portion of the present volume to give even the briefest *résumé* and the shortest practical list of illustrations. We can, therefore, simply show the reader the general nature of a blowing engine as used in blast furnace work.

The modern blowing engine belongs to one of two classes into which this form of mechanism is divided—namely, the indirect or slow-speed, and the direct or high-speed blowing or blast engine. The indirect or slow-speed, which is the oldest of the modern forms, in general design and appearance closely resembles the old or Watt's form of beam steam engine (see the series of papers on the Steam Engine in this work), and a fair notice of its general features will be derived from a glance at fig. 2,

Plate CLVI., which is a rough diagrammatic sketch of the largest blowing engine of this class which, we believe with only one exception, was ever erected—namely, that of the celebrated Dowlais Iron Works, in Wales. In this diagram *a* is the blowing cylinder, or that in which the blast is produced, and passed into the "main" or discharge pipe *b* to the hot-blast furnace, a description of which will be given in a succeeding paragraph. The piston of the blowing or blast-producing cylinder receives its motion through the agency of the beam *h h*, parallel motion and piston rods. The steam cylinder, in this case high-pressure or non-condensing, is supported in massive foundation framing, *g g*. Some idea of the gigantic character of this engine, which sends some 44,000 cubic feet per minute through the blast main *b*, at a pressure of nearly 4 lb. per square inch, may be derived from the following:—The diameter of the steam engine cylinder *c c* is 35 in., with a stroke of 13 ft., working up at a steam pressure of 50 lb. to the square inch at boilers to a power of 650 horses. The diameter of the blowing or blast cylinder, *a*, is 12 ft. (144 in.), with a stroke of 12 ft.; diameter of main in blast pipe *b*, 5 ft. The beam *h h* of this large engine is a ponderous mass, made in two parts, weighing, with its joints or gudgeons, no less than 44 tons. The pedestal carrying the brasses or bushes in which the gudgeon of this huge beam work is supported by a wall *l l*, 7 ft. thick. The beam *h h* is connected with the shaft of the fly-wheel *i i*, in itself a mass of 35 tons, some 12 ft. diameter, by the connecting rod *k*. To insure stability and steadiness in working this powerful and ponderous engine, the foundation supporting the cylinder is very strong. This is formed of a cast-iron framing, *g g*, weighing some 75 tons, which is carried and supported by a mass of masonry having a solidity of some 10,000 cubic feet.

The Blowing Engine for the Blast Furnaces (*continued*).

The other class of blowing engine—namely, the direct-acting high-speed blowing engine—is illustrated in the diagram in fig. 3, Plate CLVI. In this the cylinder is primarily supported by a vertical framing. The "blowing cylinder" is below the steam cylinder, a portion of which—the blowing cylinder—is worked from a cross head by sliding in parallel guides, and which receives its motion from the main crank-shaft by side levers or rod. The forms of blowing engines of this class are numerous, varying according to the notions of the designer; thus, the blowing cylinder is in some cases placed above the steam cylinder in place of below as in the diagram. But in all cases the principle of connection of the acting or impelling steam-engine cylinder with the blowing cylinder is direct—no beam, as in fig. 2, Plate CLVI., intervening between them—is adopted in diagram in fig. 3, same plate, being a representative one of this principle. A much higher speed of working the blowing engine is attainable by this direct-acting mechanism than in the case of the indirect principle as illustrated in fig. 2. Thus, if we take the average piston speed per minute of the indirect form at 250 feet, which may be considered as an average speed, we find that direct blowing engines have been worked up to a speed as great as that of a railway or locomotive engine, which often goes up to 800 feet per minute. A lower speed than this—some 500 to 700 feet—may be taken as the practice.

Mechanism of the Blowing Engine.—Air Cylinder and Valves.

In both classes or forms of blowing engines, as thus illustrated, the principle of the production of the blast or current of air by an arrangement of valves in the blowing cylinder is the same, and to this we now direct the attention of the reader. Let *a a a' a'*, fig. 4, Plate CLXVII., represent the cylinder, with its piston *b* moved up and down alternately by the rod *c*, actuated by one or other of the engine movements illustrated in figs. 2 and 3, Plate CLVI. This cylinder is provided with an external casing, *d d*, which acts as the cool or fresh air supply chamber, air being supposed to have access to it from the external atmosphere by the pipe or aperture shown at *e*. Communication is made between this chamber *d d* and the interior of the cylinder *a a* by means of two apertures, one at top at *f* and the other at bottom at *g*,—that at *f* leading to the cylinder at the upper side, *a a*, of piston; that at *g* to the under side, *a' a'*. Both of these apertures are provided with flap valves, which close and open the orifices according to the direction in which the piston is moving. In the diagram, fig. 4, Plate CLXVII., the piston *b* is supposed to be moving downwards from the top *a a* to the bottom *a' a'* of the cylinder. The upper valve *f* is therefore open, as shown on a larger scale at *h*, thus admitting the air from the casing *d d* to the upper side *a a* of the piston *b*, while the lower valve *g* is closed, as shown in larger scale at *i*. By this arrangement, while one valve is open, giving free access to the air, the other is closed, preventing its passage in that direction. The curved arrows 1, 2, at *h* and *i*, indicate the course of the air in relation to the valves; the straight arrows 3, 4, the direction of motion of the piston *b*. We thus see how far the supply of air to the cylinder in the upper side, *a a*, of piston *b* is supplied from the air chamber *d d* through the opening of the valve *f* or *h*, and how it is prevented from passing to the chamber *d d* again by the closing of the valve *g* or *i* from this under side, *a' a'*, of piston, and this during the downward motion of the piston *b*.

THE BUILDING AND THE MACHINE DRAUGHTSMAN.

CHAPTER XXIII.

How to Project Building Plans in Perspective (*continued*).

We began in last paragraph of preceding chapter to describe the putting in of the details, commencing with the windows, which must be all drawn on the plan. As the windows on the first floor differ from those on the ground floor, and the plans of both, if drawn on the outline plan, would cause great confusion, the plans of the ground-floor windows should be first drawn on the plan (in pencil), put into perspective, and then removed with indiarubber from the plan; the first-floor windows can then be proceeded with, and in turn rubbed out to enable the windows over them to be inserted. Presuming the plans of all the windows on the ground floor visible from the point of sight A to have been drawn on the outline plan, connect the various points of each window plan with the point of sight A by means of a set-square or straight-edge, and mark off the intersection on the picture plane; then from the ticks marking those intersections draw the vertical lines of the windows on the perspective below, between the continuous ground-floor window-sill, which has been already drawn, and the string-course over the ground-floor window-heads. Then mark off the various heights of these windows on the respective height lines, including the top, bottom, and splay of the stone window-heads, the lines of the horizontal mullions and the horizontal joints of all the stone quoins. From these heights marked on the "height lines" draw the lines on the perspective converging towards the respective vanishing points; the windows of the front elevation must of course be worked to the vanishing point V^1, and those of the garden elevation to the vanishing point V. Three lines of height will be required for these ground-floor windows—namely, H^2 for the front drawing-room window, H^3 for the dining-room window, and H^4 for the bay windows of the garden elevation. When all the ground-floor windows have been inserted in the perspective, the window plans on the outline plan must be rubbed out and the plans of the first-floor windows inserted in their place, to avoid confusion; the "ticks" on the picture plane should also be rubbed out. The process of drawing the first-floor windows in perspective is exactly the same as that just described for those on the ground floor. Join each portion of the plan in turn with the point of sight A, by aid of the set-square or straight-edge, and mark off the intersections on the picture plane; then draw vertical lines from these ticks to the first-floor window-sill of the perspective below. Next mark off on the respective height lines the heights of the stone heads, horizontal mullions, and stone quoins, and connect these points with the vanishing points V and V^1, using V^1 for the windows of the front elevation, and V for those of the garden elevation. For the window of bedroom No. 2 the height line H^2 will be required, for the windows of bedroom No. 3 and of the linen closet the height line H^3, and for the windows of the garden elevation a special height line formed by prolonging the line of the slight projections in which they are placed until it intersects the picture plane, and then drawing of course the vertical height line from the intersection down to and at right angles to the ground line.

For the small openings in the gables of the front elevation, and the two-light window in the upper story of the tower, repeat the process described for the first-floor window, using the same height lines. To put the front door into the perspective, draw the plan of the door opening, door-frame panelling, sky-light, stone quoins, and steps on the outline plan, join the various points of this plan in succession with the point of sight A by means of the set-square or straight-edge, and tick off the intersections on the picture plane; then from these intersections draw the vertical lines of the front door where required on the perspective below. Next mark off all the heights of the front door on the height line H^3—namely, the apex and springing of the various members of the arch, the stone transverse quoins and the framing or panelling of the door—connect the various points on the height line with the vanishing point V^1, and draw the horizontal lines of the front door. The only remaining architectural features which have to be put into perspective are the chimney shafts: the plans as they appear above the roof line must be drawn on the outline plan in their respective positions; a height line will of course be required for each chimney shaft obtained in accordance with the rule already given—namely, by continuing one of the sides until it intersects the picture plane, and then drawing a line through the intersection down to and perpendicular to the ground line. The various points of the plans of the chimney shafts must be in succession connected with the point of sight A by means of a set-square or straight-edge, the points of intersection on the picture plane ticked off, and vertical lines drawn from the intersections to the roof below. The various heights of the chimney shafts must then be marked off on the respective height lines, and the horizontal lines of the chimney shafts drawn by connecting the points on the height lines with the vanishing points. If the height line is obtained by prolonging the face of the chimney shaft parallel to the front elevation, then the vanishing point V must be used; but if the face of the chimney shaft parallel to the garden elevation has been prolonged, then the horizontal lines must be drawn to the vanishing point V. This is, of course,

an application of the rule stated in the preliminary portion of this paper.

The whole process of putting the elevations shown on Plate III. into perspective has now been described —commencing with the main vertical and horizontal lines and terminating with the minor features of the building; if it had been ten times the size, the process would have been the same,—more height lines and vanishing points would probably have been required, but no variation in the principles of the system of working.

The reader will no doubt have noticed that many portions of the building shown on Plate III. are concealed when put into perspective. Thus, the lower portion of the corner M^1 on the outline plan, Plate IV., is concealed by the projecting bay window of the library, but the upper portion appears above it; the window lighting the recess in the hall adjoining the porch is concealed by the tower, and the portion of the garden elevation between the bay windows cannot be seen from the point of sight A.

It is usual to complete the perspective drawing by more or less shading or etching. The roof is generally distinguished from the walls by having the horizontal jointing of the slating or tiling indicated on it; these lines must be drawn to one of the vanishing points,— thus in the tower roof the side facing the front elevation must have its shade lines converging to the vanishing point V^1; for the side facing to the garden elevation the lines of shading must converge to the vanishing point V. The shading or etching of the walls must be completed in the same manner: thus he fronts of the bay windows facing the garden elevation must be shaded or etched with lines converging to the vanishing point V, whilst their sides which are parallel to the front elevation must be shaded or etched with lines converging to the vanishing point V^1. The same rule applies to the two sides of the tower and of the gable end containing the dining-room window.

Human figures, horses and carriages, cattle and trees are frequently introduced into the perspective drawing: they must necessarily be drawn in accordance with the same rules which regulate the perspective of the building; their position must be indicated on the plan, a line of heights obtained in the usual manner, and the exact height of the proposed figures ascertained by connecting the heights marked on the height line with one of the vanishing points. Shadows may be drawn on the geometric elevations, and can be put into the perspective drawing by the application of the principles of perspective. Finally, the drawing may be coloured more or less elaborately, with sky, foreground, and the surroundings of the building.

We now proceed to the important work of the draughtsman connected with one or other of the two great classes of constructive work—architectural and engineering—which concerns itself with what is frequently if not generally termed "setting out" the lines of working drawings in the various departments of building and mechanics.

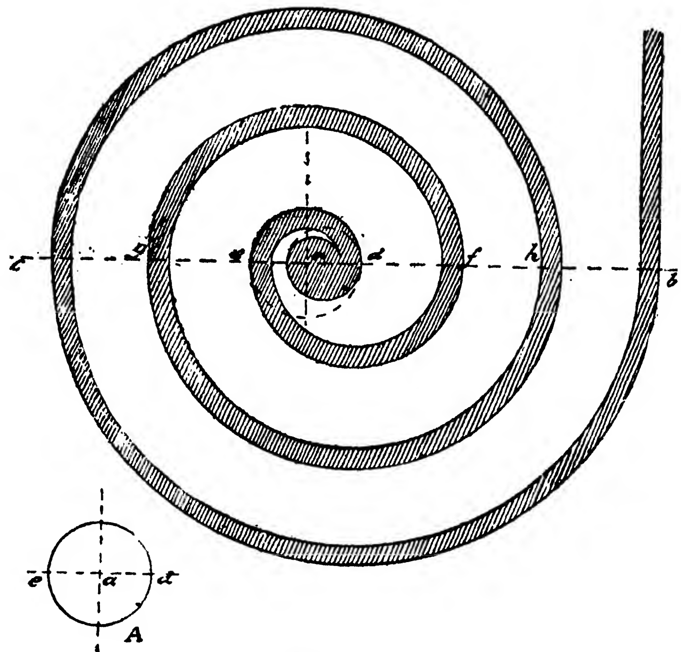


Fig. 42.

Constructions connected with the Spiral.

The first department to which we direct the attention of the reader is that of constructions or working lines connected with and based upon the spiral. These will be found applicable to the work of the builder as well as to that of the machinist. A "spiral" is a line generated by revolving round a fixed point. Fig. 42 illustrates the geometrical or common spiral; in this *a* is the centre or eye, and through the centre a line *b c* is drawn, which forms the centre line of all the convolutions. With the diameter of the eye *a* as a radius, from the point *d* describe the semicircle *e f*; from the point *a*, with *a f* as radius, describe the semicircle *f g*. From the point *d*, with radius *d g*, describe the semicircle *g h*; and from the point *a*, with radius *a h*, the semicircle *h c*. The points *a* and *d* are then taken alternately as the centres of the semicircle, and the radius of each semicircle is always the distance from the point being used as a centre to the point of termination in the line *b c* of the semicircle last described. All the semicircles described from the centre *a* are above the line *b c*; that from the centre *d* below it. The spiral in fig. 43 is produced as follows:—Let *a b c d*, diagram C, be the eye of the spiral. It is divided, as shown in the larger scale, as at A in the figure. Draw, as in this diagram A, *e d*, *g f*, at right angles, intersecting in the centre *a* of the eye, and divide the quadrants in the points *b*, *h*, *c* and *k*, and join them as in the drawing. From the corresponding points in diagram C, *b*, *h*, *c* and *k*, draw lines *b l*, *h r*, *c q*, and *k j*, at right angles to the lines *b c*, *h k*, producing those lines as in the diagram C in the figure. Then, from the point *f* as centre, with distance *f c*, describe the arc cutting the line *h i* in *n*. From the point *e*, with distance *e n*, describe the arc *n o*, cutting the line *b l*. From the point *g*, with distance *g o*, describe the arc *o p*, cutting the line *k p j*; from the point *d*, with distance *d p*, the arc *p q*, cutting the line *c q i*. From the point *e* as centre, with *e r* as radius, describe the arc *r l*, and from *g*, with radius *g l*, the arc *l j*, cutting the line *k l*. In place of the spiral joining the eye *a* by an abrupt line, as at *n c*, it will look better if it be made gradually to flow into the eye, in the manner shown in diagram B in the figure: this may be done by hand.

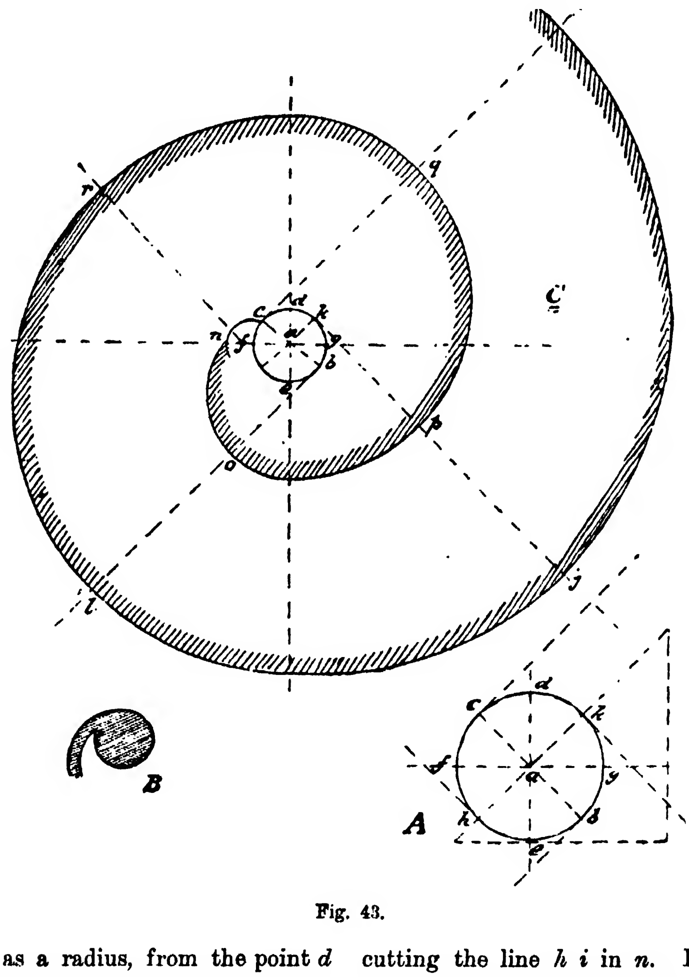


Fig. 43.

THE GEOMETRICAL DRAUGHTSMAN.

FIGURES AND PROBLEMS OF PLANE GEOMETRY, USEFUL IN TECHNICAL WORK.

CHAPTER XVI.

HAVING in preceding chapter exhausted the problems or constructions connected with straight or right-lined figures, we come now to those having curved lines as their chief characteristic. Of these the most important is the circle.

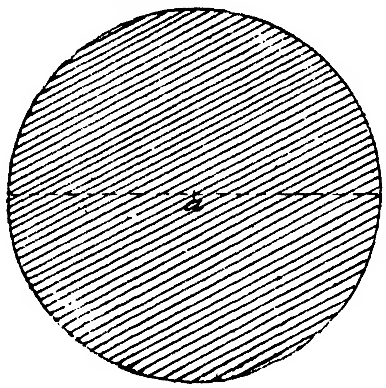


Fig. 86.

The circle is the surface inclosed by the circumference, which is described from a point, as *a*, fig. 86, called the centre, and which is equidistant from all points of the circumference. The surface of a circle is equal to the circumference multiplied by the half of the radius; for the circumference may be considered as a regular polygon, of an infinite number of sides; it is then the perimeter of the circle which, multiplied by the half of the radius, will give its surface. We may also obtain the surface of the circle by multiplying the square of the radius by the number 3·1416.

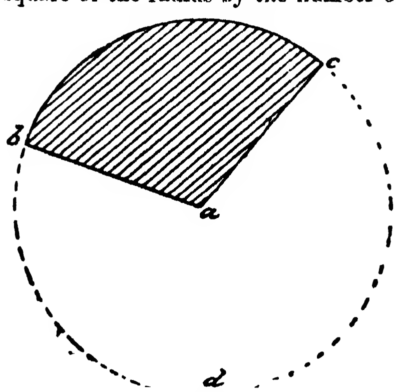


Fig. 87.

We call by the name of circular sector, or simply sector, any part of the circle *a b c d*, fig. 87, inclosed between two radii, *a b*, *a c*, and the arc *b c* which they intercept. A circular sector is simply a sector. The measure or area of the sector is equal to the arc, *b c*, comprised between its sides, *a b*, *a c*, multiplied by the half of the radius, *a b*. Thus, a sector of which the angle of the two radii is 110° would have as surface the $\frac{110}{360}$ of the surface of the circle of the same radius.

We call by the name "segment" a portion of a circle comprised between two parallel chords, as *a b*, *c d*, fig. 88, or between a chord, *e f*, and its arc, *e g f*.

A segment, *e g f*, formed by a chord *a f* and its arc *e g f*, is equal to the sector formed by the two radii *h e*, *h f*, led to the extremities of the arc, less the triangle *h e f* comprised between them, and the chord *e f* of the segment. The segment *a b c d*, formed by two chords, is equal to the segment *e f a b*, subtended by the largest chord, *a b*, less the segment *c i d*, subtended by the smallest chord, *c d*.

Curvilineal Figures.

Of these there are a great number, of which the greater part are formed by different arcs of circles having different centres and radii. The principal curvilineal figures are: the circle, the ellipse, the

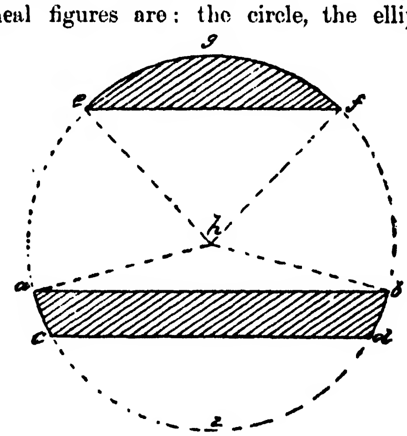


Fig. 88.

egg-shape, the oval, the spiral, etc. All these, save the circle and ellipse, will be found described in the papers entitled "The Building and Machine Draughtsman."

We now return to the circle, to give a practical means of drawing it without the aid of the compass. Construct a square, *a b c d*, fig. 6, Plate CCXV., having for a side the diameter of the circle which we wish to draw.

We divide each side of this square into two equal parts; each of these parts is then divided into a number of subdivisions, larger in proportion as we wish to obtain a figure nearer the true shape of a circle. In the figure the subdivisions are in number six, and are numbered beginning in the middle of each side of the square, so that those on the opposite sides are numbered in the same order, the number 1 being in the middle of the one side and the number 6 in that of the other. In joining by straight lines the corresponding numbers in the adjacent half-sides of

the square, we obtain a regular polygon, which will be nearer the true curve of a circle in proportion to the number of parts into which the sides of the square are divided. The more numerous the intersections, the greater the number of points obtained through which the curved line is to be drawn.

We see, then, by the inspection of this diagram, that we can substitute for the curve of a circle a regular polygon of a great number of sides, since the diagram, presenting a sufficiently regular circle, is formed by a polygon of only twenty-four sides. This method of finding points in curved lines by intersecting points of straight lines drawn in different directions is applicable to a great variety of constructions of curvilineal figures, and will be found amply illustrated in this paper, and in the series of papers entitled "The Building and Machine Draughtsman."

We now give a number of constructions in connection with the circle, the first of which is a method of dividing the arc of a circle, A M B, fig. 89. Let M

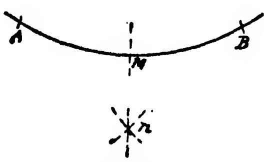


Fig. 89.

be the middle required of this arc: the point M is equidistant from the points A and B, because equal arcs, A M and M B, are measured by equal chords. The point thus is found on the perpendicular raised in the middle of the straight line A B, and this is done as already shown. We have only to remark that, the extremities A and B sufficing, there is no need to draw a straight line between them,—this is assumed.

To describe a circle which will pass through three given points.—By having three given points not in a straight line we can always describe a circle; and the problem gives the means of solving this other—namely, an arc of circle being given, to find the centre of its circle. It is sufficient, in fact, to take three points at will on the arc of circle given, and to make the construction which would serve to find the centre of a circle which we wish to make pass through these three points. To find the centre of a circle passing through the points a, b, c, fig. 90. Bisect the lines joining these points—namely, a b, b c—in the points m, m', and through these draw lines perpendicular to them, m o', m' o: the point o of their intersection will be the centre of the circle. The lines joining the three points a, b and c, form a triangle a b c; it results thus from the construction that perpendiculars raised from the central points, as m o, m' o, m'' o, or points of bisection, m, m', and m'', of the three sides a b, b c, a c, if prolonged sufficiently, will intersect in the point common to all the three sides.

To describe on a given straight line a segment inclosing or containing a given angle.—One can

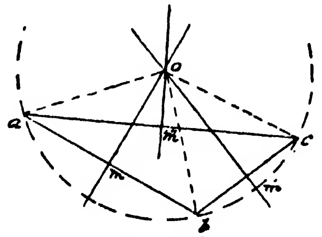


Fig. 90.

imagine a solution of this problem by means of the combination of several problems already solved, but the construction here given presents a simplicity which makes it preferable to any other. Let A B, fig. 91, be the straight line on which we wish to describe a segment, A M B, containing a given angle. Amongst all the angles having their summit on the arc A M B, and consequently having as measurement the half of the arc A M B, we select the one which is formed by the line A B and the tangent to the point B. If the arc A N B was the arc wanted, the angle A B C would be equal to the angle given. We know besides that the centre of any circle obliged to pass through two points a and b is on the perpendicular raised on the middle of the line a b. Thence is deduced the following construction. At one of the extremities (B, for example) of the straight line given, draw a straight line, B C, which makes with it an angle equal to the angle given. Raise a perpendicular on the middle, m, of the line A B; and also at the point B a per-

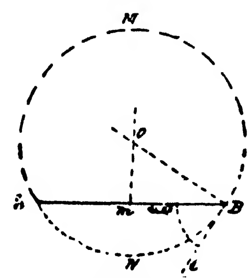


Fig. 91.

pendicular to the line B C; these two perpendiculars intersect at a point o, which is the centre of a circle of which the segment A M B solves the question. It will be perceived that we might repeat the same construction below the line A B, but that the result would be an arc of circle equal to the arc A M B.

To find a tangent to a given circle.

First, let M, fig. 92, be a point placed on the circumference of the circle. Since the tangent is perpendicular to the radius of the point of contact, we have only to draw the radius O M to the point M. A perpendicular to this line M O, as *t* M *t′*, is therefore the tangent required.

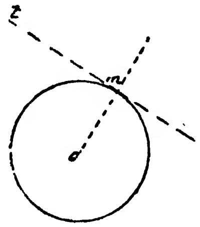


Fig. 92.

In the second case let M, fig. 93, be a point outside the circumference O; let there be a line, M T, passing through this point and tangential to this circumference and let X be the point of contact. If we joined O X, this line would be perpendicular upon M T. We know then that if we join the point of contact wanted, X,

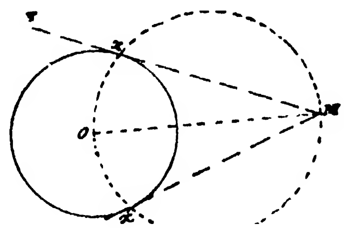


Fig. 93.

to the points O and M, which are given, the point X should be on a semicircle described on the line O M as diameter; and as it is essentially a part of the circle O, it should be found at the meeting of the two circles, and the tangent M T will then be determined. Symmetrically there will be two tangents:

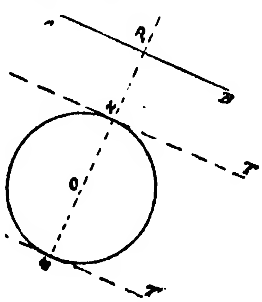


Fig. 94.

the one below the line O M, as T′ X′ M′, the other above, as T X M.

In the third case, where the tangent is to be parallel to a given line, when the construction is completed, T X, fig. 94, will be the tangent parallel to A B. The radius of the circle passing through the point of contact X is perpendicular to the longest line T X; and by consequence to the given line A B, to which the tangent is parallel. If we drop a perpendicular O P upon the right line A B given, it will cut the circumference of the circle in the points X and X′, if prolonged or extended so as to pass through the centre O. At these points draw the tangents, as X T, X′ T, and they will be parallel to the line A B.

A point being given, as in fig. 95, either within or without a given circle, to draw through this point a straight line upon which this circle cuts off a given length,—first, when the point M is in the inside; second, when it is on the outside; but we shall only describe these two cases in one explanation, as it is identical for both of them. Let A B be the length which the part cut off should have. All the equal chords which we can inscribe in a circle are equidistant from its centre; they are then all tangents to a circle concentric to the first, and having as radius the distance of any one of these chords. Hence this construction: inscribe in the circle given a chord equal to A B; drop O P perpendicular to this chord;

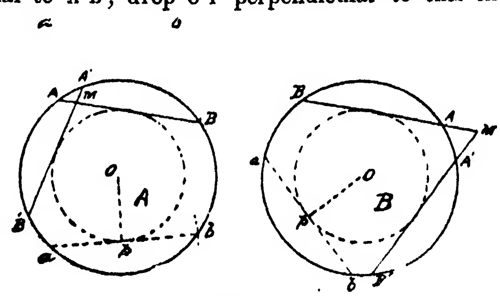


Fig. 95.

with the radius O P describe a circle, to which we shall merely have to draw one or two tangents according to circumstances.

Curvilineal Figures.—The Ellipse.

Having in preceding chapters given various constructions connected with lines, and of figures from the triangle up to the circle, we now come to those connected with what are sometimes called the curvilineal figures, otherwise and more frequently by the simple term curves. These are the "ellipse," the "parabola," and the "hyperbola"; and of these the first only—the ellipse—is strictly entitled to the term curvilineal figure, inasmuch as, like the circle and the straight-lined figures as the triangles and polygons, it inscribes or bounds or incloses a space or surface. The other term, "curve," is more strictly applicable to those curved lines or curves of which we have named two, the "parabola" and "hyperbola"; to which are now to be added the "cycloid," the "epicycloid," and the "involute."

THE WORKMAN AS A TECHNICAL STUDENT.

How to Study, and What to Study.

CHAPTER XI.

In continuation of what was given in the last paragraph of preceding chapter we have to remark that it is not so much that the student possesses much, or would desire to know more, as that he determines of what he has to make the most. Now, in this work of self-improvement, self-help is one of the most important factors. And this self-help consists, as the very term indeed shows, in the way in which he applies himself to it. If he be not self-determined to do his very best to secure success, that success will never at its best be obtained by him. In reality, all the help, which the ablest teachers and the most valuable books can give him, will not be given him to any practical purpose, unless he aids their influence by his own individual efforts. All the help he can possibly get from without will be of no avail to him in his practical work of study, unless he works steadily from within. It is but the expression of a very commonplace truth to say that the work of a man can only be done by the man. Commonplace though it be, it is, however, but too commonly overlooked, or, if known, neglected; with no end of unfortunate results, as wasted lives and useless spasmodic efforts of many but too abundantly testify.

Self-Help and Self-Advancement in Life of the Technical Workman as a Student, secured by a Combination of Intellectual Effort and Attention to certain Individual or Personal Peculiarities or Idiosyncrasies.

And here also the reader will perceive the other point to which our remarks lead up—namely, that this self-help and self-advancement in life can only be secured by the combination of intellectual effort with what are called moral attributes. On this point, indeed, we have already said something; it will be necessary for the purpose we have in view to say more. And in this we trust that we shall be able to realise the hope we held out, that we might be able to show how closely it concerns the student and his success in life, that in his studies as in his work the peculiarities of human nature, as we find it practically existing amongst us with ourselves and those we come in contact with, must be taken into account and made subservient to our practical purpose. We have indeed broadly stated that the neglect of this factor in the problem to be solved had done more than aught else to retard the true and the rapid progress alike in personal life and in technical study which the truth would secure. This position we hope to prove by what we have yet to say on this vitally important subject of the workman as a technical student.

We have said that different individuals have different and differing gifts. This is so self-evident, some reader may remark, that it serves but little purpose to tell us what every one knows. But while every one may agree as to a fact, it by no means follows that all are agreed as to how that fact is to be dealt with or utilised. So here, while the truth of the fact we have stated is self-evident, yet it appears that, although believed in, it is not acted upon. For how comes it that, if gifts differ in different individuals, no account is taken of the fact in the practical education of the individuals, but all are treated on the same uniform plan, whether that plan be good or bad, a single Procrustean rule being applied to all? Procrustes, we should inform the reader (for we do not approve of using terms or names which may not be understood), was a tyrant of ancient classical times, who had a bed for his visitors. If the length of this suited that of the intended occupant, well and good, the tyrant was content; if he was too tall or long, his feet or ankles were cut off to shorten and fit him to the bed; if too squat and short, the visitor was stretched out on the rack, with the same ultimate end in view. It is to be hoped that Procrustes had but few on his visiting list.

Practical Injury done to the Cause of Technical Education by enforcing One System upon all Students alike, overlooking certain Important Facts in their Lives.

Now, this custom, which, unfortunately, is the rule in our educational systems, of forcing all the pupils to pass through, and conform to, a certain rule, a single or uniform system, must, like the bed of Procrustes, torture some; it cannot possibly work easily with all. No doubt, it may be said that in teaching it is not possible, from the mere number of the pupils, to have a system for each, so that it will suit his peculiarities. Procrustes would, questionless, argue that his system, amongst others of its advantages from his point of view, was, at all events, an economical one, as one bed would be made to do for many, and it evidently did not suit him to remember that for one class of his visitors no preliminary operation of fitting was necessary, as what would hold a tall would clearly contain a short man. So it certainly is cheaper, or, at all events easier, to have one system of teaching, allowing it to suit as best it can pupils of varying character, than to have each pupil taught in such a way that his progress will be insured and the best education given him in the quickest way. It may be that the very number of the pupils to be dealt with in ordinary schools compels a uniform system of this nature. But more could be done if more were desired in the common-sense way of nature. One was asked if he could play the violin, to which he replied that he thought he could, but that he had never tried. Teachers may think that their usual system cannot be altered or modified to meet the actual condition of pupils. Have they ever tried? Do they generally try? That some do try is

a doubt, and they are the successful teachers; but then, with them teaching is a science, not a mere trade or piece of handiwork, which no matter how it is done, if done some way, regardless of what the real results are, is considered finally done.

For let the fact be here remembered, which unfortunately is too frequently forgotten, that education is not like the mere taking of a predetermined amount of objects and endeavouring to cram them somehow into vessels of varying size; when the small vessels have too much allotted them for their capacity, while the large ones have too little, and some are altogether neglected, and have to be content to be taken empty away. Education is not like this. It is a process of assimilation of a certain pabulum, so to say, calculated to strengthen; and if any one organ of the assimilating body be weak, the first object to be secured is to strengthen that organ, if possible. Food may be of the richest quality and most nutritious, yet if the power of digestion be weak or altogether disorganised, or if the individual have tetanus or lock-jaw, so that he can neither masticate nor swallow, what then? One may starve in the midst of plenty. And how many go forth from scholastic systems of the most complete character, where no end of knowledge is offered, almost wholly uneducated! The diet, so to say, did not suit their system, and no effort was made to strengthen their system so that it could. This system is like that of some medical men who are not true physiologists, who, for example, in treating cases of weak eyesight in young people, give them spectacles—which themselves are an evil—simply to get out of the difficulty in the easiest way. The true doctor would like to strengthen the eyesight, and tries to do that. But it is so much easier, requires only the minimum of thought, to use a palliative than to devise a cure.

The Great Advantage of the Individual or "Self-Help" System of Technical Study.

These and like considerations have the closest possible bearing upon the progress of the technical student. So far as that progress is dependent upon teachers, he must take their systems as he finds them, for there is beyond a doubt a difficulty in even the best of teachers changing or even modifying their system to suit various capacities and capabilities. He will presently see, however, that he may do much himself to help the system to assimilate it to his known capacities. But in the case of a student who is mainly dependent upon a system of self-help or self-education, it is obvious that, as here he has no one to control him, he has no excuse for not exercising his reason in deciding on the details of the system best fitted for his *own* capacities and capability. We do not here mean—and this we wish the student distinctly to understand, for the point is of vital importance—that this system is that which only refers to, or includes, the subjects in the departments of knowledge which he wishes to acquire; the system no less includes, as an essential part of it, that discipline of his mental habits by which this acquirement is greatly aided. We might almost say mainly aided. For, just as the capacity or cubical bulk of a vessel dictates or regulates the number or quantity of objects or material which it can receive, so in like manner, at the outset or start in his self-education, the technical workman as a student may find that his capability to study, or his capacity for the reception of the facts and truths of knowledge, may be very limited. And just as we can conceive of a vessel being so constructed that while in its usual or normal condition it can only contain a certain bulk of matter, it is also capable of expansion, so that when occasion demands it shall hold more;—so the student will find that his mental capacities or capabilities of reception and assimilation of the truths of knowledge can by cultivation be made to expand and receive and retain greater powers than before existed.

And so comes it that what we have insisted upon as an essential part of education, required in all systems in face of it, but absolutely needed in that of self-help and self-education, must be carried out, if true progress be desired, and this is close attention to the facts and circumstances of individual existence—the idiosyncrasy, so to say, of the student. It is idle to say that, as this involves the consideration of habits which, according to popular definition, come under the head of moral training, it has, therefore, nothing to do with that of the intellect. Idle! for this moral training may go to get rid of a habit which, where it exists, if it be not directly antagonistic to all progress, may yet very greatly retard it; and surely it is worth while to try to get rid of it. For, if progress be not desired in any walk, why begin to go in it? Better to save oneself the trouble of the first effort, if the second is not to be taken. As we have said, so we say it again, and it will bear repetition, we must take facts as they lie before us, human nature as it is. And as human nature in any special case—that is, the individual—is a compound made up of strange and often startlingly diverse faculties and habits, use of which will and does exercise an influence upon everything which the individual does, surely it is but practical common-sense wisdom—so called, we presume, because in a good many walks and works of life it is not common at all—so to deal with and treat those that they shall be subservient, and not antagonistic, to the work we have to do in life. We are by no means alone in the belief that education generally would be much more valuable as a real help to this work, if more attention were paid in scholastic systems or treatment to their dual nature. We may partition off, so to say, these faculties as intellectual, those habits as moral, as if they

have no connection with each other, and could and do act quite independently of each other, never crossing or intermixing with each other; but despite all our care, or rather perhaps from having no care at all in the matter, they will get intermixed and interwoven, whether we will or no. The web, so to say, of humanity is made up of two threads of yarn, that of warp and that of woof—the intellectual and moral qualities of man; and this fact must and does influence work of every kind done by us, and can no more be left out of consideration than can the part of Hamlet be cut out from the play of that name, if it is to be a play at all. The various points involved in this dual condition of man as it affects the education of the technical student, will come up for reference and consideration, as we treat the subject in a closely practical way, and in attempting this we would first draw attention to an important point in the system.

"Order" in Study, or the Sequence with which the Facts and Truths of Technical Knowledge are taken up by the Student, a Point of Vital Importance.

This is the order or sequence in which the facts and truths of knowledge, open to the student, are taken up or availed of by him. Much time is lost and effort weakened through having an irregular system, —which practically is tantamount to having no system at all, for system is essentially regular. The habit of taking things in sequence, or what may be called the natural order, is one which should be cultivated, forming, as it does, one of the points of discipline through which the student should be put, or better still if he put himself. The acquirement of the truths and facts of technical knowledge may begin with the teacher, his teachings being followed by those of books and by the observation of the student. But here it should be carefully noticed by teacher and student, each giving the most earnest heed to it, that if the proper kind of *education* be not followed, no real progress will be made. That is, it must be the continual and persistent application of the mental discipline, the educing or leading out of the powers of the mind; this we have already dwelt upon and enforced, only at this stage reminding the teacher and student alike of its vast importance. It may be safely asserted that the great advantages of observation, for example, to which we have referred, will be hopeless of attainment if the mental discipline, or the education of the mental power, has not been strictly and carefully followed up. Goethe has made the profoundly pregnant observation, that the eye sees only what it has the power to see; there is thus such a thing as the education of the eye, in order that it may be able to look at and positively see things. For, as the thoughtful reader will perceive, things are often looked at, in the popular acceptation of the word, which yet, in the true sense, are not seen at all; inasmuch as the mind takes no cognisance of them, and the memory has no record of them in its marvellous pages. It is the same thing in the discipline or work of observation of things lying around us, all of them full of practical worth, but only in so far as they can be truly observed. The mind must take a firm grasp of them before their full force and significance is realised.

Great Value of the Habit of Observation to the Technical Student.—Practical Points connected with it.

This point now named must be taken special note of by the student, for it involves, or rather is, the most important consideration in, and makes clear the error of the popular notion that seeing and observation are precisely the same thing. There can be no greater mistake than this; and holding this notion, and, what is worse, acting upon it, gives rise to great evils. Although a man sees a thing, it by no means follows that he comprehends or understands what he is looking at. It would be more correct to use the term "looks" than that of "sees." For a man may look at a thing—indeed, cannot help, to use the above and the common phrase, seeing it—yet the mind takes in no intelligent comprehension of what the eye has seen, must have seen, could not, in fact, avoid seeing. Seeing, truly explained, is understanding what is seen. Observation, therefore, which is but another word for the same thing—seeing—is a dual process: a physical one, in the first instance, that is, looking at the thing; and second, a mental one, taking in and comprehending what the object looked at really is. Goethe remarked, as we have already quoted, that the eye only sees that which it has the power to see. Hence it is that the difference arises between men as to their ability to take note of the circumstances by which they are surrounded. This point may be illustrated by the curious story of two African travellers, who were companions during a long journey of exploration in that country, passed through the same districts, and had, of course, presented to them the same general objects. Yet, when the two returned to head-quarters, they had two very different stories to tell as the result of their travels. One of the travellers might, like the "needy knife grinder" in the clever verses of Canning the statesman, have replied in the same words, when asked to tell his story, "Story, sir! why, sir, I have none to tell." It was in truth so. While his fellow-traveller had a perfect budget of facts connected with the districts through which both had passed, he had nothing scarcely to narrate. To his mind the journey had been simply a long series of alternate walkings, eatings, and sleepings—"only this! and nothing more." Everything to him had been negative; the other had found something positive. Amongst other facts of the observant

traveller he named one, that they had passed through a district in which elephants abounded, more especially in one part of it, which was thick with elephants' tusks,—a mine, so to say, of ivory. As little had his companion "seen," to use the common expression, either the elephants or the tusks which some of them and their predecessors left on the ground,—so certain was he that he had not seen the one or the other, that those at headquarters began, and reasonably, to doubt the accuracy of statement of his companion. This accuracy was, however, ultimately proved by after exploration, and the information he had given as to the locality of certain places, etc., etc., was shown by others who followed him to be absolutely correct. Thus, in the case of those two travellers, both had seen the same objects; he who had no story to tell must have seen what beyond a doubt his companion saw. The whole difference between the two was, that while both looked upon the same things, the one not only looked, but saw what his eyes, as Goethe says, had the power to see in the usual sense of the term—the only sense, indeed, in which seeing can be valuable: that is, his mind took an intelligent impression of the fact that he *had* seen, so that once seeing in this comprehensive, intelligent reading-way only the exertion of his memory was afterwards required so that he could remember what he had seen. On the other hand, his companion had merely looked at or seen what he could not well avoid doing, he not being blind, but which had only been reflected on the retina of his eye, and had not sunk deeper to penetrate his mind or brain.

True, like one who looks in a glass and going away "straightway forgetteth what manner of man he was," this traveller may have seen and yet forgotten that he had seen, and what. So that it may be said that after all it was only a matter of memory, and a question between the two as to which had the better one. Now, although we shall have something to say presently as to what part memory plays in the technical education of the working man, and how important that part is, it is to be recollected that before one can remember he must know; which seems to be about as absurd as to say that before you can have a thing you must possess it. But, absurd as the statement may appear to be, it conveys, like many other paradoxically absurd statements, a sober and an important truth, one very often and easily overlooked or forgotten—not always, indeed, understood. Observations, therefore, to be of any value, must be intelligent; the facts or the story told by them must be read; properly speaking, without intelligence there can be no observation. If the reader, not quite intimate with the inner or leading meaning of words, not merely of those purely technical but of those used in ordinary writing and conversation, wishes to know what we precisely mean by the above sentence, when saying that facts must be "read" before they can be of value, he should under the word "intelligent" consult the "Cyclopædic Dictionary of Technical and Trade Terms" in this work, giving the derivations of words.

The Habit of Sound Observation can be greatly Cultivated, like any other Gift.

Some are gifted with remarkable powers of observation, taking the term in the above, the only true, conception of it; some have it only moderately; while others seem to be totally deficient of it. That it can be cultivated is beyond a doubt. Some do not believe this, or, at all events, act as if they believed it not. As the muscles of the brawny arm of the blacksmith, which look like knitted and knotted wire, were not formed at first, but got stronger and stronger the more he wielded his hammer, so the power of the eye to see can be and is strengthened by its judicious use. And this judicious, common-sense use is exemplified by the experience and practice of the blacksmith. He did not at first, in his apprentice days, take up the heaviest hammer, and try to give with it the hardest stroke upon the iron bar resting before him on the anvil which men could give. He began by degrees, and each week's work found his arm the stronger and his eye the quicker, till at last, like old Thor, he showers down upon the hissing hot iron blow after blow, and this with a hammer which he could scarcely have lifted, far less wielded, in his youthful days. So by slow and sometimes painful effort we can cultivate the power of observation. Some student may say, How can I cultivate what I have not got? To which we reply, How do you know you have not got a gift or do not possess a certain thing? A man often has in his house a certain object of the existence of which he is absolutely ignorant,—so much so that if asked if he had it, he would at once say he had it not; and quite truly. And he would, under ordinary circumstances, only become cognisant of the fact that he did possess it when some occasion showed that he required it, and the necessity to have the object might, before he went elsewhere, urge him to look over his own stores. The first step in getting or finding a thing is to be impressed with the wish to have it. Before any student, therefore, decides that he has no power of observation, let him try to find out whether he has or no; and this can only be done by exercising it. The very first exercise of it, we venture to say, will result in his being able to exercise it a little easier the second time; and each successive effort will bring increased strength to make

THE GRAZIER AND CATTLE BREEDER AND FEEDER.

THE TECHNICAL POINTS CONNECTED WITH THE VARIETIES OR BREEDS OF CATTLE—THEIR BREEDING, REARING, FEEDING, AND GENERAL MANAGEMENT FOR THE PRODUCTION OF BUTCHERS' MEAT AND OF DAIRY PRODUCE.

CHAPTER XXII.

The Pasturing System in Relation to Certain Habits of the Stock Fed under it.

BUT there is another and a most important point yet to be considered in relation to the system of pasturing. And it involves a very important point in practical feeding—namely, that the quickest return for the food consumed is obtained when the animal being fed or fattened is allowed to remain quiet. All animal or physical exertion or fatigue is virtually expenditure of food. And all food which goes to meet the demands of physical exertion is just so much lost to the process of adding to the flesh or fat of the feeding animal. Food is their vital force, and if, as in the case of the horse, we desire to have that force expended in carrying or dragging work we feed the animal with this end in view,—so much only of the food being allowed to go to the keeping up of the physical condition of the animal. We do not feed a horse to fatten him, but to get muscular force out of him. The case is different with fatting cattle and with dairy cows. In the case of the cattle we wish to get as much as possible of the food we give them returned in the shape of juicy joints of flesh and fat; in the case of the cows as much as possible—without otherwise injuring the condition of the animals—in the shape of milk rich in butter and caseine. Now, the production of these articles is greatly aided by keeping the animals in a state of rest and freedom from all worry and excitement. This rest or repose, so conducive to the formation of fat and the production of milk, can be obtained to any due extent by the system of soiling or house feeding—it cannot by that of pasturing. In the system of out-field pasturing the animals keep roaming about nearly the whole of the time they are out, with the exception only of the time they are lying down to chew the cud or ruminate. This roaming about the field is not only for the purpose of finding out the best grasses, but to avoid the patches of grass to which we have already alluded, and those also which have been recently fed upon or off by other animals, or even by themselves individually. For grass recently breathed upon or salivated is rejected by them for that which has only the fresh air and the dews of heaven resting upon it. This perpetual roaming about requires so much exertion to be made, and this so much food to be consumed, which otherwise would have gone to the products particularly desired by the feeder. And the evils of this state of continued restlessness are, of course, greatly aggravated in hot weather, when the attacks of the flies are so persistent and painful, that to escape them the tortured animals are kept in a state of perpetual excitement; and but too frequently they are goaded—or gadded (an appropriate technical term in connecting the gad-fly as a special cause of this animal torture)—to fly or gallop to and fro over the field in a too vain attempt to get rid of their tormentors.

All this is most detrimental to the process of fatting cattle, or of milk production. And another cause of loss in pasturing arises from the lack of uniformity in the temperature to which the animals are subjected. All food which goes to keep up the heat of the body only is so much lost in the way of fatting or in milk producing. If we can keep the bodies of the animals in a temperature sufficiently high to make them, so to say, comfortable, none of the food they have partaken of is required to go specially to the production of the heat necessary to keep up the temperature of the body to the point required. This can be done with comparative ease in the system of house feeding or soiling, where shelter from cold winds and biting frosty air can easily be secured. It cannot be done in the system of pasturing, where the temperature, however cold, cannot be raised, and where, as an almost universal rule, little shelter from cold winds and none whatever from drenching rain can be obtained.

The Soiling or House System of Feeding Stock.

It is for reasons such as those we have now named that advanced agricultural opinion is wholly in favour of an extension of the soiling or house-feeding system Even the most ardent advocates of the pasturing or out-field system admit that it has grave defects; and these the most enlightened advocates of it try to get rid of, or at least lessen, by various practices. Some of those we have alluded to, such as tethering the cattle or cows to one particular part of the field—so that after feeding off the rich grasses they lie down and allow the food they have consumed to go to its legitimate uses. The field, in such a system (which, however, has been very sparingly introduced into practice), is of course so divided into lots or parcels that any one lot fed off is not returned to by the animal; and if the field is of small extent, another is taken, until the first-fed-off lots have recovered their grasses in large measure. Others who adhere to the pasturing system, fully aware of its defects, endeavour to get rid of some of the worst of them by providing shelter sheds into which the animals can go.

But there is yet another point which closely affects the question as between the pasturing and soiling or house-feeding systems; and that is, that of the value of grass as a food compared with other feeding substances. Valuable as grass is, as forming one of the varieties of food upon which cattle and dairy cows are

fed, and as taking part in those changes in feeding found to be so beneficial to them, it is not *per se* so nutritious as other foods which can be cultivated by the farmer. However clearly this is shown by chemical analysis, it may be however questioned whether there is not a "something" which chemical analysis fails to detect in grass, which gives it, if it gives nothing else, that flavour which seems to make it the most grateful food to the ruminating animals of the farm. That the least economical method of feeding farm stock upon grass is that of pasturing them upon it, we have no hesitation in stating; and if our readers will remember what we have said as to the system, they will probably agree with this opinion. By adopting the soiling or house-feeding system, cutting the grass over different parts of the field, or from fields bearing special crops of what are called artificial grasses, such as Italian rye grass and other succulent crops, taking them in rotation, and carrying it to be eaten by the stock in the house, the largest amount of economical feeding will be obtained.

Details of the Soiling or House-feeding System.

The grass land in this system however, it is scarcely necessary to say, should be kept in the highest condition of cultivation. It is but too frequently the case that in many districts this is so far from being the rule, that an authority has declared it to be his opinion that, taking the average of the grass lands throughout the kingdom, they yield but little more than half of what they would or could do if they were attended to as carefully as other parts of the farm. Whether this be a true estimate or not, certain it is that grass lands could be made to yield much more than many now do by superior cultivation, and the system of house-feeding would, as we have seen, lend itself admirably to and greatly aid this superior cultivation. The crops of grass obtained from fields from which cattle were excluded would be larger than those got from them under the ordinary system, where they are admitted to them. One great benefit would certainly be obtained by more careful cultivation of grass lands,—and that is, that the weeds would be got rid of. Few comparatively are aware of the extent to which weeds are grown from year to year as part of our pasture grasses, to which they give no value, but, on the contrary, tend greatly to deteriorate it. To such an extent are they permitted to form part of pastures, and so firm a hold are they allowed to take of the land, that they may be said to dominate in many fields, forming actually the largest part of the produce. Now, weeds cannot stand against, so to say, high or good cultivation. The administration of farmyard manures, with judicious applications of certain artificial ones, such as the nitrogenous manure known as nitrate of soda, will, along with other careful management, soon cause weeds and noxious and poor grasses—which, in fact, ought to be classed as we class them, as weeds—to disappear, and their place to be taken by grasses of a superior kind. The seeds of these may be judiciously sown down. But it is a curious fact, well known to many practical farmers—who, however, do not always make the knowledge practically valuable to them—that under superior cultivation the weeds which it compels, so to say, to disappear, are replaced by superior grasses, which have been present in the soil, but which have remained dormant while the weeds or noxious grasses have had possession of the ground. For it is a curious circumstance that while weeds, if left alone, not only continue to grow, but to develop themselves towards perfect growth, becoming better and stronger every season, good grasses, if left to themselves, deteriorate gradually, die out, and are succeeded by weeds, which have the greater inherent dominating power. This, beyond all doubt, although deemed to be different by many who grumble at it, is a wise and beneficently ordained law. It clearly offers the best incentive to well directed labour; and it promises, with few chances of those promises being unfulfilled, a valuable return for such labour as may be given. The point is beyond dispute that our grass lands are capable of great improvement, and that if careful cultivation were given, as a rule, to those throughout the kingdom, we should add by it very largely to our feeding resources, and so directly lead to an increased number of cattle being fed, thus again adding greatly to the food resources of the people.

Succession of Crop Cultivation for Stock Breeding.

But while this is true, and while the lesson it conveys should not be lost sight of, the fact remains that the feeding resources of our farmers would be increased in the most direct and most profitable way, not by extending, as has been so widely advocated of late, the acreage of our grass lands, but on the contrary by increasing that of our arable lands—that is, by adding to the variety and number of our feeding crops, making these subservient to a well devised, carefully thought-out and judiciously applied system of house-feeding or soiling. We have seen that while our food crops are exceedingly limited in number, feeders in other countries have at their command a much greater number. And of those it may be said that they are all capable of being profitably cultivated in this country. But even taking such food crops as we already possess, and which are cultivated with such success by so many of our advanced farmers, we have enough to induce us to carry out a more profitable system of cattle and dairy-cow feeding than that which is the rule in this country. What is wanted is not so much the introduction of food crops at present unknown to our farmers, or if known not cultivated by them, as the extended cultivation of those with which they are

already familiar. We do not, however, advocate the the doing away with pasture and meadow grasses as part of the food-producing lands of our farmers. Meadow land will always be required; and pasture grasses will always, under a judicious system of feeding, take a useful part in the changes of feeding which this system will demand. But we do advocate the extension of a system which will do away with a considerable proportion of grass lands which at present are anything but productive, and which, even under better cultivation than is now given them, cannot yield the same amount of feeding produce as the same extent of land put under arable culture, for the raising of a variety—more or less wide—of nutritious food crops. But if in the future grass lands be still the leading food resource of our feeders, we nevertheless maintain that they never will yield the profitable results under the present system of out-field or open pasturing as they will do if used in conjunction with the systems of soiling and of house-feeding.

We have now to explain, as briefly as may be, what are the peculiarities of the soiling and house-feeding system here and in various parts of this chapter alluded to. The terms here used are often considered as synonymous, but there is in practice this clear distinction between them. The term soiling is generally used in connection with the word summer—"summer soiling,"—and this in correct technical language means the system of keeping up the animals in the house during the summer months, or throughout a certain part of them—supplying them with grass cut from the fields, whether this be natural or artificial grasses, such as Italian rye grass, clover, etc. House feeding—which is perhaps more widely, as it certainly is more definitely termed "stall feeding"—on the contrary, is that system on which the cattle or cows are "kept up" or "housed" all the year round; necessitating a particular kind of farm cultivation to supply them with certain feeding substances, and the adoption more or less of what are known as "artificial," or more popularly "cattle foods." The practical difference between the two systems known as "soiling" and "stall feeding" may be said to consist in this,—that stall feeding means the housing or feeding of the cattle or cows under shelter throughout the year, while soiling is house feeding during a part, and this the best part of the year, and hence the term summer soiling, by which it is best known. Summer soiling is frequently adopted, not from any idea that the principle of house feeding is the best and the most economical, but because from one circumstance or another, such as a dry season or the like, the pastures are too poor to admit of grazing, or the heat is so great as to make the gad-fly—a plague at all times to poor cattle exposed to its attacks—a greater plague than usual, and from the circumstance that there may be good crops of artificial grasses; or, if a greater degree of forethought has been given to the cropping of the farm, a fair supply of some special food, such as cabbages, rape, green rye, or vetches. This latter circumstance alone almost invariably decides the farmer to adopt the "summer soiling" system; inasmuch as it takes no great degree of experience to know that the only economical method of consuming such special crops is to cut them and take them to the house where they are supplied to the animals, precisely in the same way as hay, turnips, or artificial foods are given under ordinary circumstances of house feeding. And one would from this be inclined to expect that farmers, seeing the economical advantages of thus giving cut food under what they call unusual or abnormal circumstances, would, as a matter of course, try or at least thoughtfully consider the advantages of the system of house or stall feeding as a regular part of the work of the live-stock farm.

The Soiling System (*continued*).

Whatever the reason, it is, however, the fact—and it is with facts that practical men have to deal—that house feeding, whether it be occasionally adopted, as in summer soiling, or form an integral part of the ordinary work of the farm, being carried out all the year round, is but little practised in this country. Perhaps the only circumstances under which the complete adoption of the house or stall feeding system is met with, and this year after year, are those under which dairymen live in towns, where land even for exercise grounds cannot be had, or in their immediate neighbourhood, where, land being scarce and exceptionally dear, only a limited area can be had for this purpose. And even in such cases it is but seldom that the cows are turned out for a brief exercise or airing; this being confined to the calves, if calves are reared in the dairy (a by no means general system), or to sickly cows, who may not have any serious disease but are "only a little down." If we wish to know what the system of continuous house or stall feeding is, we must go to the Continent, where, taking this as a whole, it may be said to be universally practised. It is also practised, we believe, and this to a considerable extent, by at least the advanced farmers of the United States and in some parts of Canada. But wherever practised, with careful attention to its details, it affords abundant evidence that it is so far a thoroughly economical method of consuming food that, wherever systematically and carefully carried out, a certain acreage devoted to its crops will keep a much larger number of cows, or fatten a greater number of cattle, than the same acreage would do under the old, or as we should rather call it, the present system practised in Great Britain.

THE SANITARY ARCHITECT.

THE PRINCIPLES AND PRACTICE OF HIS WORK, IN HEALTHY HOUSE ARRANGEMENT AND CONSTRUCTION.—TECHNICAL POINTS OF SEWERAGE AND DRAINAGE, VENTILATION, ETC.

CHAPTER IX.

BUT while scents anything but odoriferous, and sights not all pleasant to the eye, would be a necessary concomitant of a town in the days gone by, drained on the open channel or gutter system, they would rarely—indeed, scarcely could—be in the most concentrated form; and even where the gases arising from neglected and rarely hand-cleaned or rain-flushed-out gutters were pretty strong, it would be a rare thing for such strong gases to be passed directly into the interiors of the rooms of the houses. Before they could reach the height of the open windows, through which they would most easily pass to the inside of the rooms, diffusion would have been carried out to such an extent as to render the aerial poisonous gases comparatively innocuous, if not in many cases wholly harmless. It is not at all disputed that the old gutter system of town drainage gave rise to exhalations of a noxious kind, which so contaminated the air surrounding the houses that pestilences were often thus directly caused. But the reader must take careful note of the fact that this great evil was not a necessity of the system. On the contrary, it arose from the neglect of our ancestors in availing themselves of the very advantages which the system beyond all doubt presented for preventing all danger from allowing putrescent matter to remain for a long time in the open gutter or the cesspools as frequently left open, and also from the midden or open dung-heaps. If our ancestors had but learned the lessons which every day's experience might have taught them, and which their successors did in time learn, they would have seen the connection between long neglected collections of putrescent and decaying substances, whether present in long lengths of open gutters, or more concentrated in cesspools and dung heaps, and certain forms of complaints and diseases strikingly dangerous. And if they had learned these lessons they would instantly have perceived that the very system of drainage which they had amongst them gave them remarkable facilities for getting rid of the causes of these sanitary evils. Nothing could, in fact, have been easier than to have kept their gutters clean and their cesspools in a lessened condition of danger. No doubt this would have involved labour, —it would have been a trouble to them, as all labour seems to man naturally to be,—and this labour they did not choose to give, this trouble they would not take, with such results as history tells us of. The great probability is that our ancestors did not at all perceive the close inseparable connection between dirt and disease, putrescent gases and ill-health. This, indeed, may be said to be an almost certainty; if we are to judge from the slowness with which we as a community have learned this great sanitary truth, and the still greater slowness with which we have applied it, and are even now applying it, in our public and private sanitary practice. The fact, indeed, is but too obvious, that even now there is a very large proportion of our population who have yet to learn the great sanitary truth above named—the close inseparable connection there is between dirt and disease. We thus see how great must the excuses be for our ancestors acting as they did in neglecting to make practical use of the advantages which their system of "open drains" or gutters afforded them, to keep the air of towns sweet and pure, and yet at the same time get rid of their domestic and trade refuse.

And it is a curious, and if our readers will but for a moment think of it, a most suggestive commentary upon what we hear so much of now-a-days—the great progress made by us nineteenth-century people in *all* branches of the arts and sciences—that in view of the evils which our modern system (the second era of house drainage history) of drainage gives rise to, some of our most advanced sanitarians wish that it were only possible to return to the old or first system, which we have just been considering, which in itself and if properly worked possesses all the advantages demanded by a perfect system of drainage. And we shall see, as we proceed, that the most advanced or perfect systems of house drainage now being practised are simply efforts to attach to our system of house drainage those peculiarities which constituted the chief and the safe features of the old or open channel or drain system. How this combination is proposed to be effected, and what are the features of the modern system of drainage, will now be explained.

Two Eras or Periods of Drainage Work.

In preceding paragraphs we have glanced at the two eras or systems in the history of house and street drainage—those being the open channel or gutter and the closed channel or drain systems. In the chief features of the older of these two—or the open system—there is a close application of some of its principles to the method of close drainage. This, the last or most recent development of the art, is found to be divisible into two methods or systems, each characterised by its own peculiar features. Those are, first, the earliest period of the closed drain system, in which the drains were constructed of brick or stone, sometimes of wood; the forms of these being as various as the notions of various artificers, each of whom was guided by some empirical rule or other—often, indeed, dictated by mere chance

or whim, but of all of which it may be said that they were in no wise based on what correct principles indicated. The work of this whole era of brick or stone drains seemed to be done in almost every direction as if there were no scientific rules to guide at all. And as the work of this class is by no means extinct, and is followed with great pertinacity by not a few artificers in many districts, it will be productive of some practical results if in due place we notice what its faults and errors were and are. The second period of the modern system of closed drainage introduced with a far higher scientific aim a class of work so distinguished, alike by the shape or configuration of the drains and by the material of which they were made, that it may be named as the age or period of stoneware tubular drains. The forms which these stoneware or vitrified drains assumed were two in number: the perfectly circular—to which the term tubular is perhaps most correctly given; and the oviform or egg-shaped, sometimes the oval or elliptical shaped. The circular tubes were the smallest in diameter, and were used for the minor or special house drains, from which comparatively small volumes of liquid refuse had to be carried away. The egg-shaped or elliptical drains were used for branch drains or for large houses, and where the volume of liquid refuse was considerable. The same form was also used for the large street sewers, and which according to their dimensions were made either of vitrified stoneware, as in the case of the smaller tubes circular in section, or of brick in the case of the very large sewers required for populous districts, or for the sewers of final discharge into which the whole of the minor drains led, as place or locality required. These forms or sections of the tubular drains of the last or most advanced period of house drainage were based on the strictly accurate deductions of hydraulic science, of which house drainage is in reality an important department.

Characteristics of the Tubular or Modern System of House Drainage.

In this system the drain tubes were laid in continuous lines, and so provided with means of forming water-tight joints, that when laid *in situ* or place of permanent position the collective series of individual tubes formed practically a long continuous pipe, capable of passing liquid from end to end in such a way that none of it passed through the joints to the soil in which they were placed or bedded; percolating through and saturating it with the foul matter of the drainage liquid—designated almost universally as "sewage." The form or interior section to the tubular drains was not only that which the principles of hydraulic science showed to be the best adapted for conveying as quickly as possible the liquid refuse from the houses to the place of final deposit; but the tubes were so bedded on an incline that this quick removal was still further facilitated. The small-sectioned pipes were all led as directly as possible to the street sewer, and a junction between the two carefully made. Practically, therefore, the smaller drains and the larger street sewers or drains formed a continuous hollow chamber or conduit of varying length—the primary opening of which was at or within the house the liquid refuse of which was to be removed, the secondary or final opening at the drain. There was thus formed an underground or subterranean passage, which, while it afforded facilities for the liquid to flow from the houses to the street sewer, as clearly afforded facilities for such air or gases as were from one cause or another forced or allowed under pressure to pass in the opposite direction—that is, from the sewer or from any part of the smaller drain, where gases were being formed, towards and often into the house. That this was an obvious evil will be at once perceived, and to obviate it various contrivances and methods were devised. We shall see, in explaining these, how far they were calculated to effect the object in view—namely, to prevent the ingress of gases or foul air into, while at the same time it facilitated the easy and quick egress of the liquid refuse from the house to the sewer.

Water the Medium for Conveying away Sewage Matter from Houses.

From this very general view of the features of the two periods of the modern drainage system of close drains, the early or brick and stone drains of irregular section, and the tubular, circular or elliptical drains of the stoneware period, the reader will be able to gain an idea of the chief characteristic feature of these two classes of drains. In both, whatever was the material of which the congeries of drains were formed, or whatever the shape or section, it was necessary that the sewage should be carried along them to the place of final deposit as quickly as possible. We shall see, as we proceed, that not merely the form or shape of the drain, but of the material of which it is constructed, exercises an important influence on the rapidity of the flow of the liquid through it. But, however accurate the form of the drain, and however well constructed, it is obvious, from the very nature of the refuse of a house—in great degree solid or semi-solid, and possessing substances more or less adhesive, or as we may say glutinous in character, such as grease and the like—that to get it quickly conveyed along them it must have given to it by some means or other a greater degree of fluidity than the general refuse of a house as a rule possesses; and with this increase of fluidity would come, as a matter of course, an increase of mobility or capability of being easily moved from one place to another.

THE FACTORY OR MILL HAND AS A TECHNICAL WORKER.

THE ORGANISATION, GENERAL DUTIES, AND SPECIAL WORK OF THE STAFF OF FACTORIES FOR THE PRODUCTION OF SPUN AND WOVEN GOODS—THAT IS, "YARN" AND "CLOTH"—AND THOSE CHIEFLY IN COTTON AND WOOL.—GENERAL DESCRIPTION OF THE VARIOUS PROCESSES OF MANUFACTURE.

CHAPTER XIV.

IN describing the slubbing frame, we have almost described those which follow—namely, the "intermediate," "roving," and "jack" frames. As we have before remarked, an intermediate frame is in some districts denominated a "second slubber"; and this name has arisen from the fact that the intermediate frame was not in use formerly, and when added, it received in one district the name of second slubber, as the roving frame followed the slubber. In other districts it had given to it the perhaps more appropriate name of "intermediate," as it came in between the slubber and the roving frame.

The only difference in the appearance of the "intermediate" frame, as compared with that of the slubber, is that it has an erect or frame part attached to it, so that the bobbins which are made at the slubbing frame can be placed in an upright position, where they can be so arranged that the roving can be drawn from them directly to the rollers. A pin or skewer is used, by which the bobbin is pulled round with ease, so that the roving cannot be broken or strained. This "intermediate" frame has also rovings running together, which is called "double roving," the slubber having but one. We must keep in mind that the two rovings will only be about half the thickness of the sliver which was put up behind the slubber. This intermediate frame now carries out all the operations precisely in the same way as that of the slubbing frame, as we have above described.

Practical Work of the "Intermediate" or Second Slubbing Frame.

This frame claims for its functions two things. First, although having two rovings put up behind, these are so elongated by the draft which is in the rollers, amounting to perhaps five, that the roving produced is much thinner (called "finer"). The two being only half the thickness of that behind the slubber, are further reduced to about a third the thickness of that of one of the ends from the slubber. To the inexperienced in the drawing and spinning of cotton this may appear as a useless expenditure in machinery, in the additional wages, room, and turning. This has proved to be much to the contrary. To give an example, we will suppose that a draft of six or seven had been given to the slubber instead of five. The roving at the slubber would have been so pulled that it could not have held together to be wound upon a bobbin. Another advantage is gained by having an intermediate frame; and that is, two ends are put up at the back, and this insures what is called another doubling, which adds much to making the yarn more even, and it is found from experience that short drafts are much in favour over that of long drafts in making good yarn, even and strong. Every time that the roving or sliver is doubled it will endure a greater pull (draft). The mechanism of the intermediate frame may be said to be a facsimile of that of the slubbing frame; the only difference in the work being an extra double, and a further draft by which the sliver or roving is reduced—made finer. The spindle of an intermediate frame is also lighter and thinner than that of the slubber; the flyer is also narrower and shorter, and the bobbin is shorter in the lift, and when full of roving it is less in diameter. This will be evident to all when they know that the roving is finer, and therefore less strength is in it to drag the bobbin round when put in the next frame. The intermediate frames range from 120 to 160 spindles each.

The Roving Frame.

The frame which follows the intermediate is called a "roving" frame. This frame is in every particular like the intermediate—*i.e.*, in form. The difference lies in the spindles, flyer, and bobbins. It receives its work or roving from the intermediate frame, and is reworked in the roving frame precisely as those are in the intermediate frame from the slubbing frame. Two rovings from the intermediate frame, being placed in the creel of the roving frame, are drawn with a draft of six or six-and-a-half—*i.e.*, the roving as it is delivered from the rollers is six times longer than it was when put behind the frame. So the roving is by that so much the finer. This roving frame, in coarse spinning mills, where counts do not exceed, say "forties," is the finishing frame in the frame room. The bobbins from this frame are taken to the spinning frame, be it either mule or throstle.

In a medium spinning mill, say where from fifties to one hundreds in counts are spun, and a good quality of "carded yarn" is required, another frame is added, sometimes termed a "second roving frame," or a "jack frame." This "jack frame" performs its work in the same way as a roving frame, having two rovings put in the creel and drawn into one, and is made about seven times longer but only about three-and-a-half times finer than the two together, which was put up. A finer roving is required where a finer yarn is spun; and it will be found by following each draft in each frame, as we have named, that the roving is in every process finer and finer. It is found to be of undoubted advantage to have small (short) drafts in every process, and hence the advantage of the intermediate frame for coarse counts, and the additional

frame (jack) for the finer counts. The adoption of the frames as named has been found of the utmost importance in securing good work, so that, as may be expected, they are in very general use. Our own experience satisfies us that to make a good class of yarn from a medium class of cotton they must be made use of. A little extra labour in producing yarn in a cotton mill, if judiciously applied, is by no means lost; but all other things being equal and carefully carried out, the extra labour will be seen in the extra value of the finished material.

Importance of Good Rovings—Essential to the after Processes of Spinning of Yarn.

Before we enter upon the last process which cotton has to undergo before that of spinning, we must say that good spinning is only obtained after good management in the preparing of the rovings. Good rovings can be attained only by carefully watching each and every stage which the cotton passes through, (we are now taking it for granted that a judicious and suitable selection of cotton has been made,) paying strict attention to little matters which get wrong, and without delay making them right. Little things are often neglected, being but little things and by some therefore deemed unimportant and treated as such. No foreman or manager of any concern can succeed well by neglecting small things simply because they are small things. The duty of a foreman is to be careful in all matters, be they but small; and this carefulness on his part will of necessity produce carefulness in those under his superintendence, and therefore his time will not in the end be so much needed for the apparently trifling affairs. The old adage "take care of pence and pounds will take care of themselves" can be applied to things in connection with the working of any material, and hence the importance of thoughtfulness and care in preparing for spinning. Be it understood that whatever is indifferently produced in any of the frames we have treated upon, be it much or be it little, the evil must remain. The roving is not like a painting, where the brush can take out the defect, and replace it with the required finish: no, it is there, either as complete as hands and machinery can make it, or else in an imperfect condition, and there it must remain; and in proportion as the imperfection is in the roving, so must the finished yarn be imperfect. We make these brief remarks here, at the close of our description of the preparing rooms, where the making of good thread so much depends upon the correctness of the roving. The roving must thus depend upon the past processes, however correct the roving frame may be or however well it is managed, for making a good roving. The reader will from these brief remarks at once see the importance of each process having its full attention and care given to it. Having secured a good level, even roving, we can then enter the spinning room, having a fair confidence that with good machinery and good management a good thread can be produced. Then, and only then, can the manager of a spinning mill conclude that it has to a certain extent attained the object laid out for it to secure.

The Spinning Process of the Cotton Yarn Manufacture.—The Throstle.

Up to the point at which we left off in preceding paragraph, all the operations connected with the manufacture of cotton yarn, and which we have described, are under the class of work to which, in technical phrase, the name of "preparation" has been given. All the machines described are those, therefore, of "preparation"—that is, are used to "prepare" the cotton fibres for the last or finishing processes of "spinning." In one sense spinning or twisting is performed by the "slubbing" frame and cognate frames which follow it, and which also we have described. But we have made it clear, we trust, that the twist or degree of spinning given to the cotton fibres—or "rovings," as at this stage they are called—is only given for a temporary purpose; and that the "twist" has to be taken out at the first stage of "spinning proper." This, the final realisation of all the preceding work of preparation, we now proceed to consider. Spinning is done by the "throstle" and the "mule," sometimes denominated water-frame. The throstle resembles the roving frame; and it may be that either the throstle has been taken from the roving frame for principle, or that the roving frame has been borrowed from the throstle. We should be inclined more to the latter opinion, knowing that roving frames are of but a recent date compared to that of the throstle. Before the roving-frame was adopted the system of making rovings was from a machine called a "Billy," much resembling a mule. It matters but little which of them has the priority in point of date; it is enough to say that they receive their rovings from the roving frame, and they are placed in a "creel" similar to that of a roving frame. Two rovings are run together, and when this is done it is called spinning with "double rovings."

In the coarsest system of spinning single rovings are adopted. The arrangement for drawing by rollers is like that of all other frames which have for their object that of drawing (elongating) the thread. In the throstle the draft ranges from eight to twelve—*i.e.*, it is only one-eighth or one-twelfth the thickness, therefore it is drawn out eight or twelve times the length of that in the roving as received from the roving frame. The frame consists of draft rollers, spindles with flyers attached to them, and it is driven by a belt or strap, mostly leather. The shaft, called the "line shaft," has pulleys of the

size to give the requisite speed to the spindles. The frame has a shaft, and one end of the frame, called the driving end, is furnished with two pulleys,—one screwed or keyed fast to the shaft, called the fast pulley, and the other pulley, which is on the same shaft and close to it, termed the loose pulley. When the frame is working the strap or belt runs upon the fast pulley, and when it is necessary to stop it the belt is drawn on to the loose pulley. On this shaft, where the pulleys are placed, it has attached to it a tin roller, which runs the whole length of the frame—*i.e.*, through the centre of the frame. It varies according to circumstances as to the diameter from eight to ten inches. The object of this tin roller is to drive the spindles. Upon the shaft, which is driven by the belt, a toothed wheel is fixed, and from this wheel the drawing rollers are driven. From the same arrangement of wheels the twist is regulated—*i.e.*, more or less twist can be given to the yarn by changing a wheel called a twist wheel. The spindles are driven from the tin roller by cotton bands. The spindles are provided with a little pulley called a wharve; this wharve is cut out in the form of a V. In this groove the band runs, and so the spindle receives its motion. The spindles are made to run about five thousand revolutions per minute. They maintain one speed, but the rollers are varied in speed, to effect the twist which is required to be put in. When less twist is required the rollers are made to run faster—*i.e.*, to turn more length out; and when more twist is required the rollers run at a slower rate, consequently the yarn receives more twist per inch. Twist in yarn is always spoken of by the number of turns or twists there are in the inch. Throstle yarn is always spun with more twist per inch in it than in the mule yarn. It is mostly spun from a better quality of cotton. Throstle yarn being of a rather better quality and harder twisted, it is always intended for warp yarn. The warp is the longitudinal part of a piece of cloth. This part of the cloth having the greater tension to bear, it is necessary to have all the strength that can be obtained.

Spinning of Cotton.—The Throstle (*continued*).

The throstle is well calculated to contain a larger quantity of twist than that of mule yarn. The spindles are provided with what is called a flyer (like a two-pronged fork). The flyer is different to that of a roving frame; the legs being solid, with a curl on each leg. The yarn is twisted two or three times round one of the legs of the flyer and then put through the curl. The throstle frame is supplied with bobbins on which the yarn is wound as it leaves the rollers. The twist is, of course, put in between the rollers and the bobbin, and this is done by the revolution of the spindle. The twist is regulated by a wheel called the "twist wheel." The twist wheel is varied in its number of teeth according to the number of counts required to be spun. A rule is laid down for the calculation of twist, so that the twist is uniform in all counts. The finer the yarn the more twist it requires. This is so on whatever kind of a machine the yarn is produced. The twist, nevertheless, varies in its number of twists per inch according to the purposes for which it is required. Some kinds of goods for which throstle yarn is used are required to be spun softer—*i.e.*, less twist per inch, and this gives a softer and a fuller appearance in the manufactured goods; but where a kind of material is required of a harder and sharper texture, then the twist is increased in proportion to the firmness of the manufactured article needed. Soft twisted goods seldom wear so well as the medium twisted cloth. Extra hard twisted goods rarely or ever are so durable as the more medium twisted material. Extremes in manufactured substances are often unprofitable to the consumer. Be it as it may, the change in fashion has its demand, and it must be satisfied. With this, the consumer ought not to complain of the fashionable materials wearing out so quickly. The hand which is employed to manipulate and manage the working of the throstle, as tenter, is in almost all cases that of a female.

Throstle Spinning (*continued*).

The superintendence of the room where throstles are situated is intrusted to a man of experience in the mechanical arrangement of it, as well as having knowledge of the working of it, and in making changes in counts and twists, besides having the control of the hands who are engaged in working or tenting them. He is therefore made responsible for the production, the quality of the work (yarn produced), and the conduct of the hands, and the general condition of things in the room. This being the case, he receives for his trust an extra remuneration to that of a man who is simply responsible for an individual machine and its production. The throstle frame is seldom made to contain more than from two hundred to three hundred spindles. The length varies mostly according to the position or place where they have to be stationed. We have said that the throstle frame resembles that of the roving frame by having drawing rollers, creels for bobbins, spindles and flyers; the driving of the spindles in the roving frame being by that of wheels, but in the throstle frame by that of cotton bands. The bobbin in the throstle is drawn round by the yarn which is wound upon it; it being full of twist, and the bobbins being small, it is strong enough to do it, and therefore the driving by wheels is dispensed with,—and we may say that they would be impracticable for the "throstle,"—but in the roving frame the dragging of the bobbin by the roving could not be carried out on account of the softness of the roving which is required in order that it can be redrawn.

THE CALICO PRINTER.

The Chemistry and Technical Operations of his Trade.

CHAPTER XIX.

Vegetable Colouring-Matters—Use of Catechu (*continued*).

Catechu contains (2) A colourless tinctorial principle known as *catechuin* or catechuic acid, to which are due its dyeing or tinctorial properties. This substance may be prepared in a state of purity from catechu by powdering and extracting first with cold water, which extracts the catechu-tannic acid, then treating the residue with boiling water, filtering hot, and on cooling the liquid crystals of *catechuin* are obtained. These are found to be slightly soluble in cold, readily in boiling water, and in cold or hot alcohol and acetic acid. The solution on exposure to the air slowly changes colour to red and then deep-brown, due to oxidation, and that brown insoluble substance is formed which constitutes the *brown* of catechu in dyeing and printing. This oxidation takes place more rapidly in presence of alkalies. It also takes place, and rapidly, by the action of many reagents, especially dilute nitric acid and bichromate of potash. The latter salt is applied in practice, as we shall afterwards see. (3) Brown "extractive" matters, mostly produced by the oxidation of *catechuin* and *catechu-tannic acid*, and which demand no further notice. (4) Mineral matter or ash, which greatly varies in amount and composition in different samples, but which is derived from the plant from which the catechu is made, and from mechanical impurity. This, unless of unusual quantity, is of no great consequence, and so we pass it over.

Practical Application of Catechu.—Recipes for use. We have seen that the colouring principle of catechu dissolves in water, especially if hot, and in acetic acid; and that when this solution, which is of brown-yellow colour, is acted upon by oxidising agents such as the air, especially in presence of alkali, and bichrome, an insoluble substance of a fine deep-brown colour is thrown down. The use of catechu is based upon these facts. The catechu is boiled with acetic acid at 4° T., at the rate of 2 lb. catechu cubes to 1 gallon of acetic acid at 4° T.; the dark-brown liquor is allowed to settle and the clear liquor decanted. This is then boiled with 1 lb. starch, 6 oz. chlorate of potash are then added, and the mixture cooled, and a solution of 2 oz. chrome alum in 3 gills water is added. This is printed, aged, and then either steamed or passed through bichrome, when a fine deep-brown is developed. The chlorate of potash in the colour is to aid the oxidation; the chrome alum also aids in oxidising the colour and in modifying the shade. Another method of using catechu is illustrated by the following example, which yields a dense brown: catechu 2 lb., acetic acid 4° T., treat as before, cool, and add sal-ammoniac, 3½ oz., dissolved in 1 gill water, then mix with ½ oz. verdigris pulp. Print, age two nights, and pass through milk of lime. The action of sal-ammoniac in this recipe is not definitely known; but certain it is that it so acts upon the copper of the verdigris and the catechu as to cause the more rapid and complete oxidation of the *catechuin*. Sulphate and sulphide and nitrate of copper, and probably also chloride, may be substituted for verdigris. Many substances may be added to catechu colours to modify and improve the shade, such as acetates of iron and of manganese. This method of using catechu—namely, by printing its solution—is very frequently combined with the use of garancine. Catechu is largely used in dyeing—that is to say, a mordant of acetate of iron and of alumina printed on the cloth, and fixed by ageing or steaming and dunging. This is then dyed in a solution of catechu; rich shades of brown are thereby obtained. The following mixture is an example of a catechu colour used in garancin styles:—Catechu 2 lb., acetic acid at 4° T. ½ gallon, boil, strain, and add 10½ oz. sal-ammoniac, 8 oz. acetate of copper, 1½ gill acetate of lime, 1 nog. red liquor at 12° T., and then mix with 1½ quart thick gum-arabic. Print along with the mordant or mordants for garancine, age the cloth two nights in the air, dung and then dye in garancine. The combination will consist of deep brown together with the garancine shades.

Sumac (Sumach, or Shumac)

is the dried and ground leaves, leaf-stalks and small twigs of a shrub growing in various parts of Asia, and in France, Italy, Sicily, Spain and Portugal, and named *Rhus cotinus*. It is a coarse dry powder of pleasant odour, with a greenish tinge. Water dissolves out a pale or buff-coloured liquid. The active principle of sumac is tannic acid—of which good qualities contain about one-quarter of their weight. Sumac is used as a source of tannic acid in printing and dyeing, and for the production of drab shades in printing iron mordants and dyeing up in sumac. Since the introduction of pure tannic acid at a cheap rate, sumac and divi-divi have been less used as sources of tannic acid in the dye-beck, etc., in printing.

Divi-Divi.

This consists of the pods of a small tree growing in South America, named *Cæsalpinia coriaria*. The pods are 3 inches long by nearly 1 broad, of dark-brown or black colour, and generally warped or doubled up. When extracted with water they yield a dark-coloured liquid consisting almost wholly of tannin, which is applied in dyeing for blacks, etc. Good divi-divi generally contains 50 per cent. of tannin. In dyeing, a tannin liquor is made by extracting with water, letting settle, and using the clear

liquor, which is used for dyeing upon iron mordant, especially the cotton "warp" of mixed goods.

Sapan.

This is the wood of a variety of *Cæsalpinia*, a soft-wooded plant found in Siam and Bimas. In printing it is used as an extract—chiefly for the production of a "steam-red," but since the introduction of aniline scarlet, etc., has fallen into disuse. It is used as a "spirit"-red colour in woollen printing, being printed on the cloth with an acid solution of tin, and aged in the air.

Tannic Acid.

This is generally considered as a mordant, and, indeed, acts as such in most instances in which it is employed; but as in other cases it behaves as a true dye, and is the principle in many of the vegetable compounds which we have treated above, and which are generally considered as dyes or dye-wares, we therefore treat it here.

Colouring Matters now rarely used.

It would be considered perhaps by our readers an inexcusable omission were we not to notice, even briefly, those colouring-matters which, though once important in the calico printing industry, are now only of historical interest; we will, therefore, notice the more interesting of these dyes. Some of these have been driven out of the market owing to the less cost or the greater facility of application of artificial dyes otherwise similar; others have been superseded by manufactured products which exceed in brilliance or in fastness the natural products. In other words, the *colouring principle* of some dye-wares can be produced artificially in a state of purity, and at a cost less than that of as much natural dye-ware as would yield an equal dyeing power; and again in other cases artificial substances have been introduced, which, though of different chemical nature, yield equal or brighter shades at a less cost. The introduction, in later years, of numerous brilliant and cheap organic artificial dyes has wrought extensive change in the colour-mixers' stock of dye-wares. Referring to the last few years only, may be mentioned alizarine blue, methylene blue, and auramine, as examples of dyes which have to some extent replaced some natural products.

Safflower or Wild Saffron, which has been replaced by *Saffranine*, is the product of a thistle-like annual plant known as *Carthamus tinctorius*, a native of various parts of Europe, Asia, and America. It contains at least two colouring principles: one a yellow, and the other and only useful one a *red*, named carthamic acid. The red obtained on cotton and other fabrics by safflower is of considerable brilliance, but is, to use the trade expression, as "loose as water." The method of applying it is to extract the drug first with cold dilute acid, which eliminates the yellow colouring-matters, then to extract with weak solution of carbonate of soda. The solution thereby obtained contains the carthamic acid, and is thickened and printed on the cloth.

Lo-kao or Chinese green, a product obtained by the mixture of two vegetable dye-plants—namely, *Rhamnus utilis* and *R. chlorophorus*. It yields a brilliant but loose green, the coarse powder as formerly sold being treated with solution of a tin salt thickened with gum, printed and aged in the air for several days. It is now never used in calico printing.

In describing the various colouring-matters used in calico printing, or in dealing with their preparation in the colour shop, we have given an *example* of printing-colours in the case of each substance treated. It must be remembered that in many instances other methods than those we give are employed for producing the same shade; but we have always given recipes which we have either personally found to yield good results, or are stated by acknowledged authorities—when such exist—on the subject to yield good results. Unless otherwise stated, we always give a recipe for a *medium* shade of the colour—that is, a shade which would appear of pleasant intensity or depth were it printed in a single-colour pattern.

(2) ANIMAL COLOURING-MATTER.

Only one natural colouring-matter of animal origin used in calico printing is worth mentioning, and that one is now but rarely employed—namely, *cochineal*, once an important dye in calico printing, and yet employed somewhat extensively in woollen dyeing and printing, but superseded, for cotton, by aniline scarlets.

Cochineal is a red dye-ware consisting of the dried bodies of various species of *homopterous* insects belonging to the family of *Coccidæ*, genus *Coccus*. The size of these insects is about that of a small pea, cultivated in India, Spain, Canary Islands, and other parts. The colouring-matter is *carminic* acid, which is contained in particles in the insect's body; it is soluble in water to a bright-red solution; alkalies turn it violet; strong sulphuric and hydrochloric acids dissolve it; lime and baryta water yield purplish precipitates, as also the acetates of lead, zinc, and copper. Alum does not at once yield a precipitate, but if after the alum ammonia be added, red carmine lake is thrown down. Tin crystals turn the aqueous solution of cochineal to a bright scarlet. Cochineal may be fixed upon cotton cloth by printing the solution along with acetate of alumina and steaming, or tin crystals, and long ageing.

Ammoniacal Cochineal.—Carminic acid, or colouring principle of cochineal, forms with ammonia a new compound, which is frequently the form in which cochineal is employed industrially. It is superseded for most purposes by the greatly cheaper and equally brilliant dye aniline scarlet.

THE DOMESTIC HOUSE OR HOME PLANNER OR DESIGNER.

THE WORK OF THE YOUNG ARCHITECT OR BUILDER IN THE DESIGNING OF HOUSES FOR TOWN AND COUNTRY.

CHAPTER XII.

The Two Methods of Gaining Access to the Stair common to all the Houses.

THERE are two plans or modes of building houses on the "flat" system; in one, as in fig. 8 (vol. iii., p. 139), the passage or lobby, which gives access to the staircase leading to the various stories or flats, enters at and directly from the pavement of the street, two houses being on the ground floor and entering from the main or entrance passage and lobby right and left of the staircase; the other houses in the upper stories also enter right and left of the landing. In the other arrangement the building is set back from the street pavement such a distance as to admit of a plot of ground being laid out either as a small flower garden or simply as a grass plot. In this system the lobby or passage giving entrance to the staircase leading to the flats or upper, stoey houses is flanked right and left by a large house-termed in Scotland "a self-contained house," as it has a separate entrance from the garden plot, which is shown at *o o* in fig. 9. This is entered by a gate, as at *j*, and divided by a railing and parapet wall from the pavement of the street. These two self-contained houses are reached by a short flight of steps, *l*, leading from the pathway *k* to landing *m* and front door *n*. The kitchen—and sometimes a breakfast or bedroom for the members of the family—department of each self-contained house is placed in the area, or what would be called in England the "basement" plan or floor, and is reached by an interior staircase, as also access is given to it from the outside by area steps, as shown at *h h*, fig. 9, *i i* being the "area" level by which tradesmen, etc., enter or call, so as to avoid going through the house, thus giving the same convenience as London suburban houses possess—viz., a servants' or tradesmen's entrance separate from that of the family.

The "flat" or common-stair houses are reached by the staircase from the lobby at *n n*, fig. 9, corresponding to *a a* in fig. 8. The lobby *n n*, fig. 9, of the common stair, as *b c*, fig. 8, is reached from the street *a a* or pavement *b b*, fig. 9, through the entrance gate *i*, in railed parapet walls, which separates the front garden or flower plots, as *o o*, from the pavement by the paved footpath *k*, at the end of which is a short flight of steps, *l*, leading to landing *m* in front of the door *n* to entrance lobby or passage *n n* leading to the common stair, as *b c* in fig. 8. The area space, as *l l* in fig 9 and *f f* in fig. 10, runs right along in front of the houses, however numerous those are in the row or street, and is divided into the separate "areas" given to each self-contained house, as *i i*, fig. 9, by party walls. Those are generally arranged so that they form spaces between them, and afford supporting walls for the steps and arches carrying the steps and landing, as shown in the section in fig. 10 at *g g*. Those arches are necessary in order to span the void or space formed by the area, between the first wall, *e e*, of houses and solid soil of the street and pavement at *i i*. In fig. 10 *a a* is the level of street and pavement surface *j*; *b b* is the parapet wall on each side of the passage or paved footpath *c c* in fig. 9. This parapet wall, *b b*, fig. 10, separates the passage from the area, as *i i*, fig. 9, on one side, and from the garden or flower plot, as at *o o*, on the other. The parapet wall *b b*, fig. 10, is crowned with an iron railing, *c c*. The flight of steps and the landing to the door *d* of the lobby to common stair is supported by the arch, as at *g g*. The area surface is at *f f*, and generally bounded on the street side by what is called a coal "cellar," as at *j k*. The window of the apartment *e e* in sunk or basement floor of the "self-contained house" is at *l*.

Plans of Street Houses on the "Flat" System, with Self-contained or Independently Entered Houses on the Lower Story.

Figs. 9 and 10 illustrate one method of arranging the houses when the ground floor is taken up by "self-contained houses" which are reached directly from the street by entrances quite distinct and separate from the passage leading to the common stair. When "self-contained houses" form part of the general row or street, the arrangement in plan is always, as in fig. 9, a central doorway, as *g*, being flanked right and left by two doors *n n*; *n n* being the door to the lobby or passage leading to the common stair *s*—"common" to all the flats in the upper stories—*g* being the door to the self-contained houses. But the arrangement as shown in figs. 9 and 10 is not always adopted. In many of the streets, and perhaps more especially in the wealthier and more aristocratic quarter of Scottish towns, there are no gardens or flower-plots, as at *o o*, fig. 9, between the pavement *b b* and the front *n g u* of the houses. The space between them in this alternative arrangement is wholly taken up with "sunk area" space, as at *i i*, fig. 9 in plan, and *f f g g* in fig. 10 in section. In this arrangement access is generally had to the doors of the self-contained houses and the common stair lobby by landings or broad paved spaces leading directly from the pavement without any entrance gate, the iron railings topping and fronting the space occupied by the sunk area below. These broad entrance landings or pavement spaces are generally on a level with the pavement of the street, or raised above it by one low step, the "riser" being generally of less height than that of an ordinary step. Fig. 11 is front elevation, adapted to this style, but the railings inclosing the sunk areas are not shown.

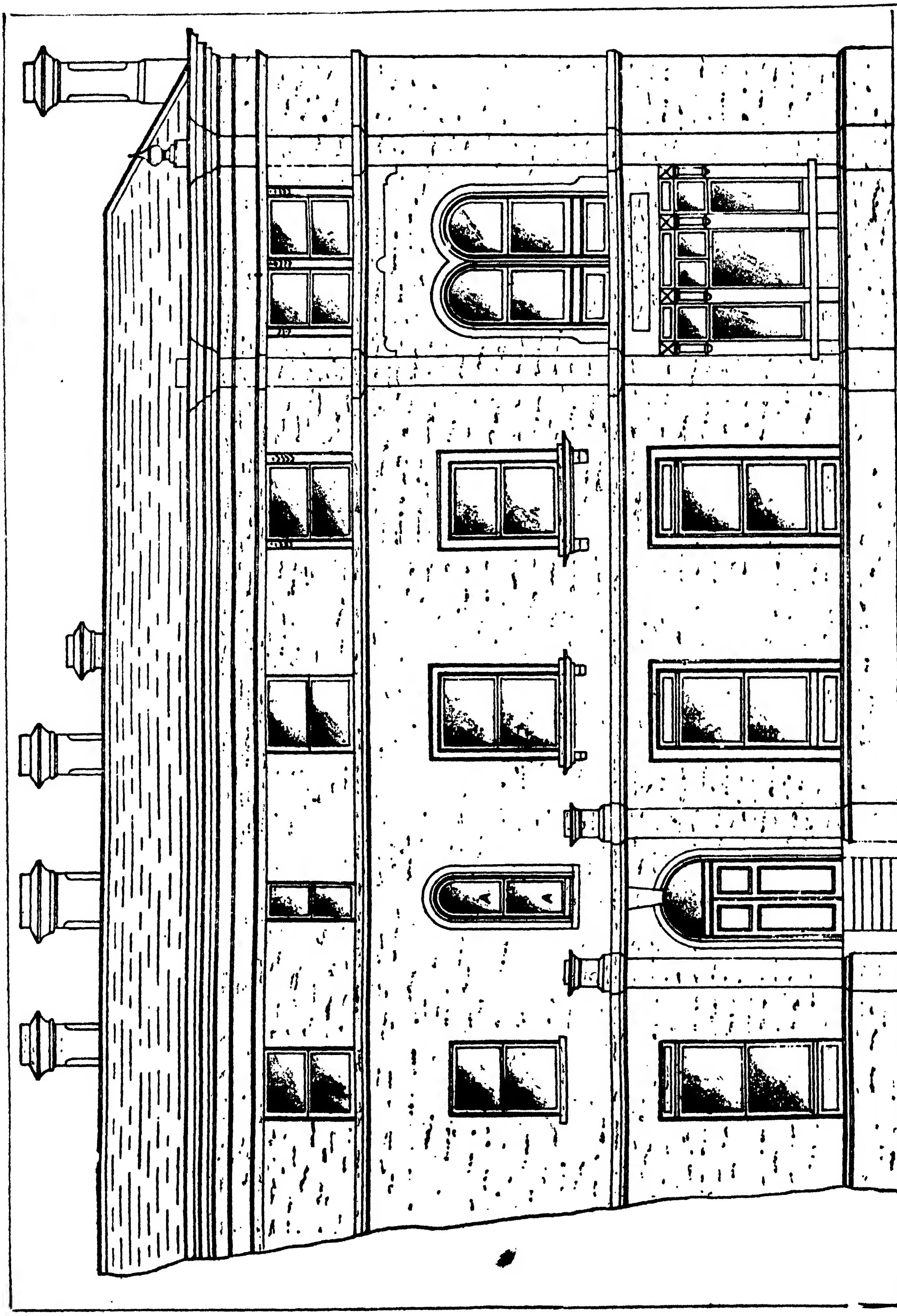


Fig. 11.

INTERSECTIONS OF SOLIDS.

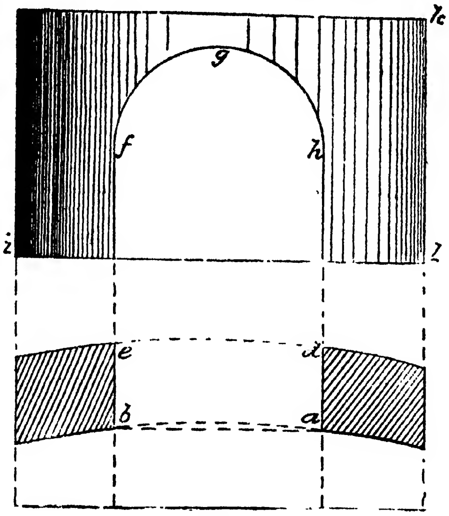


FIG. 1.

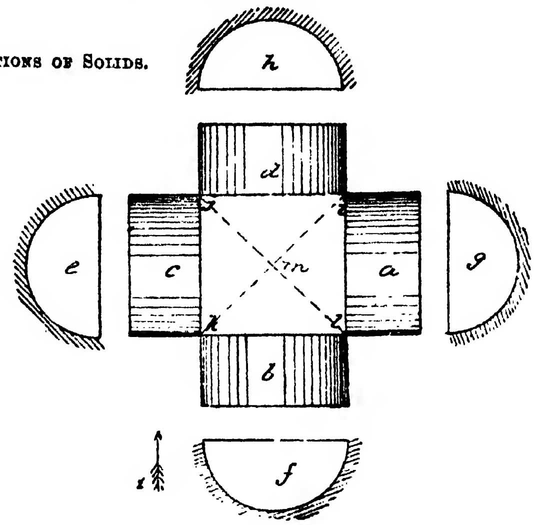


FIG. 2.

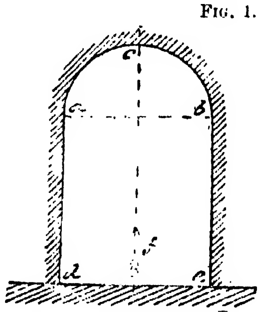


FIG. 3.

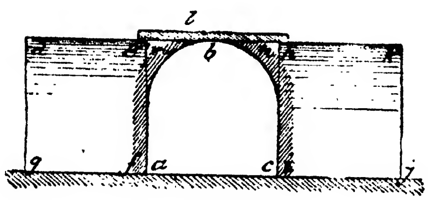


FIG. 4.

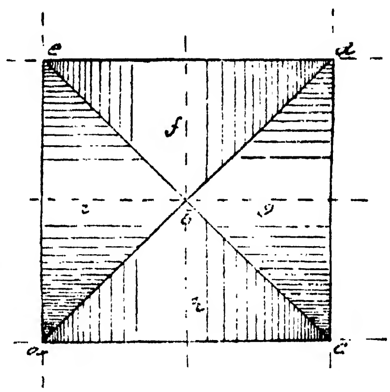


FIG. 5.

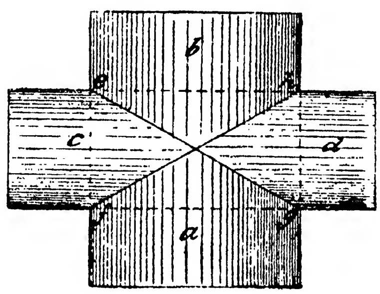


FIG. 6.

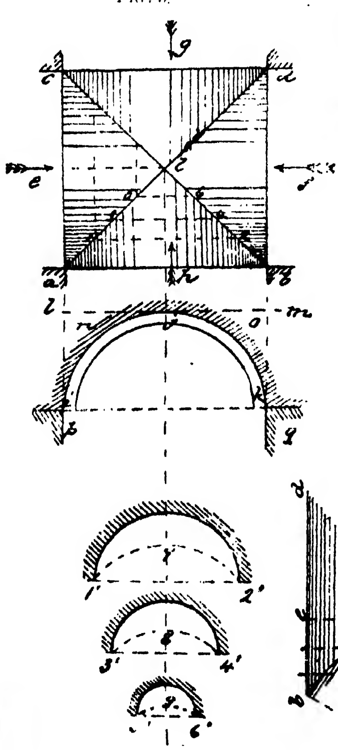


FIG. 7.

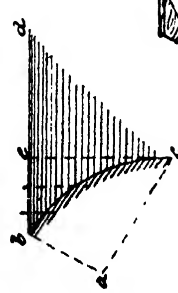
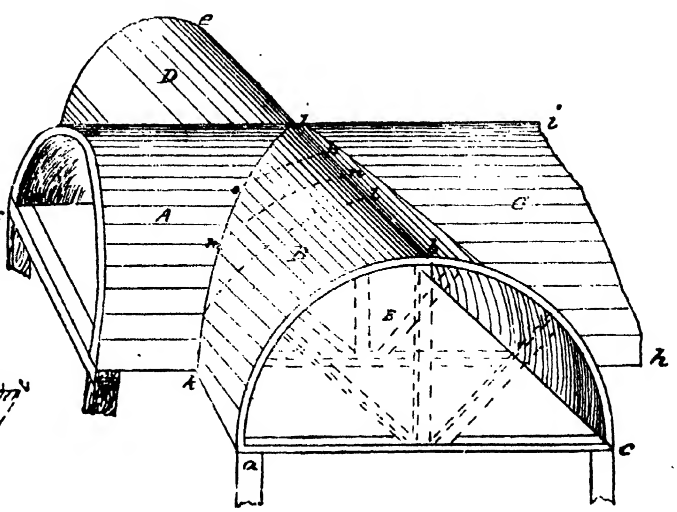


FIG. 8.



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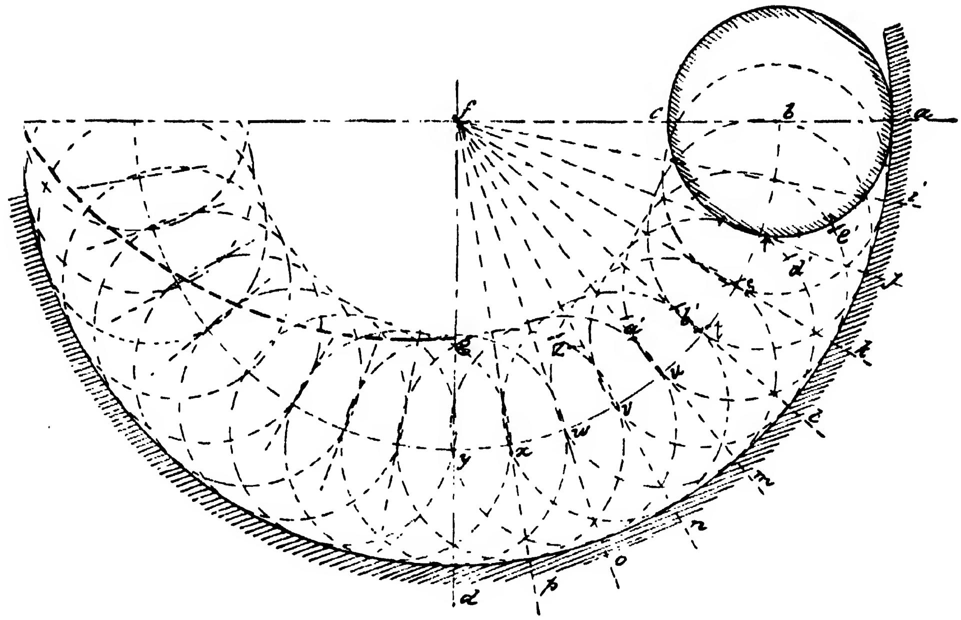

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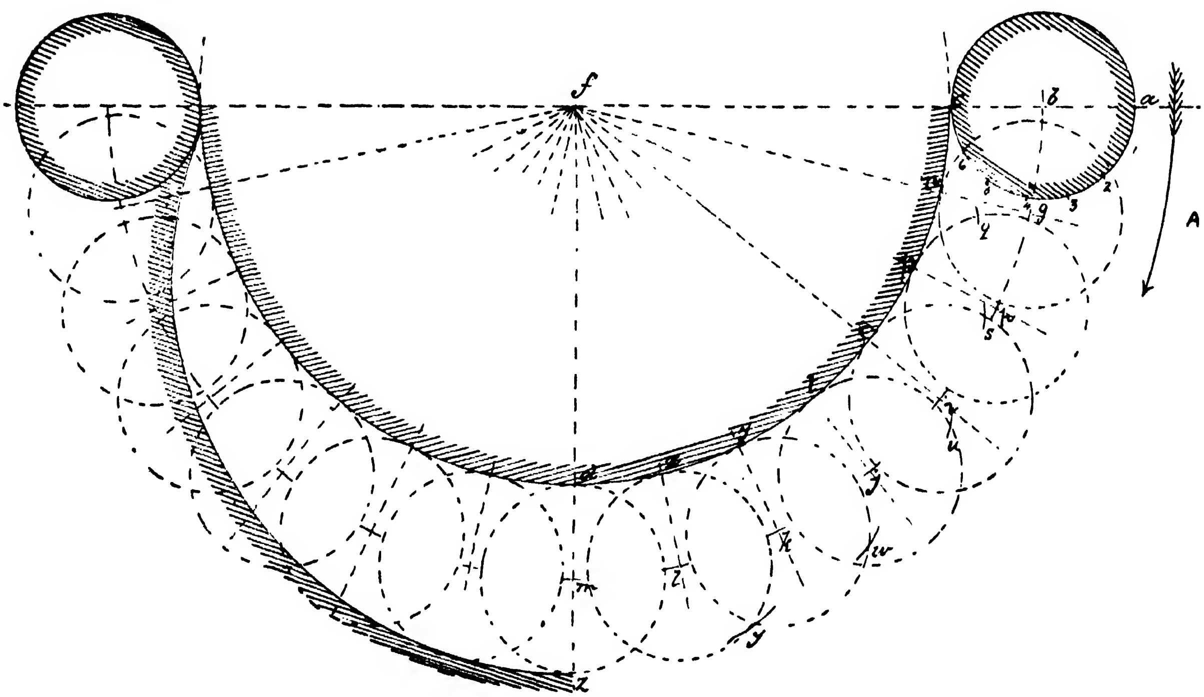

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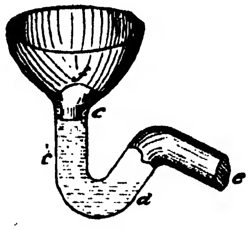

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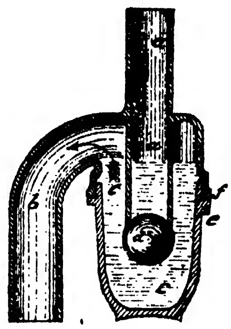

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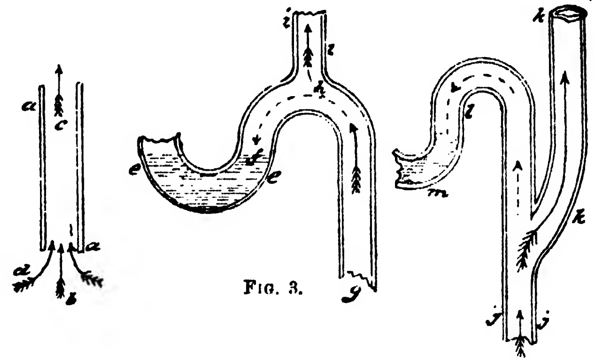

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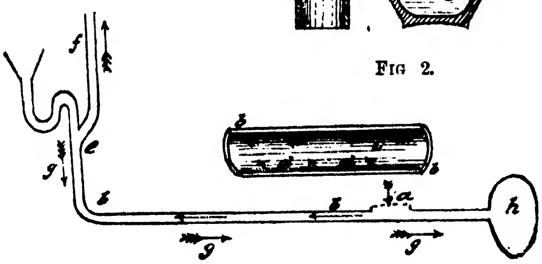

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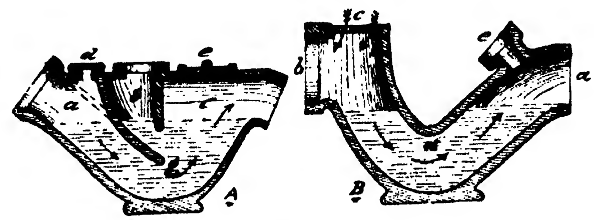

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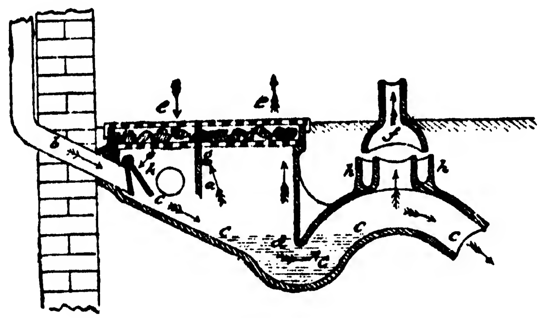

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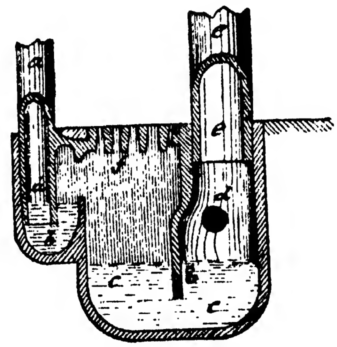

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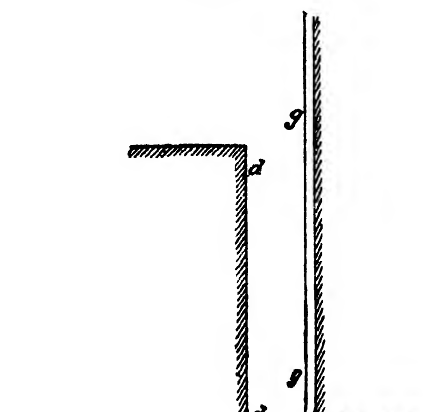

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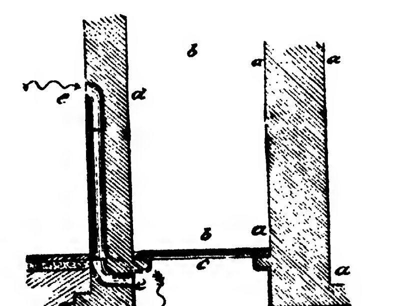

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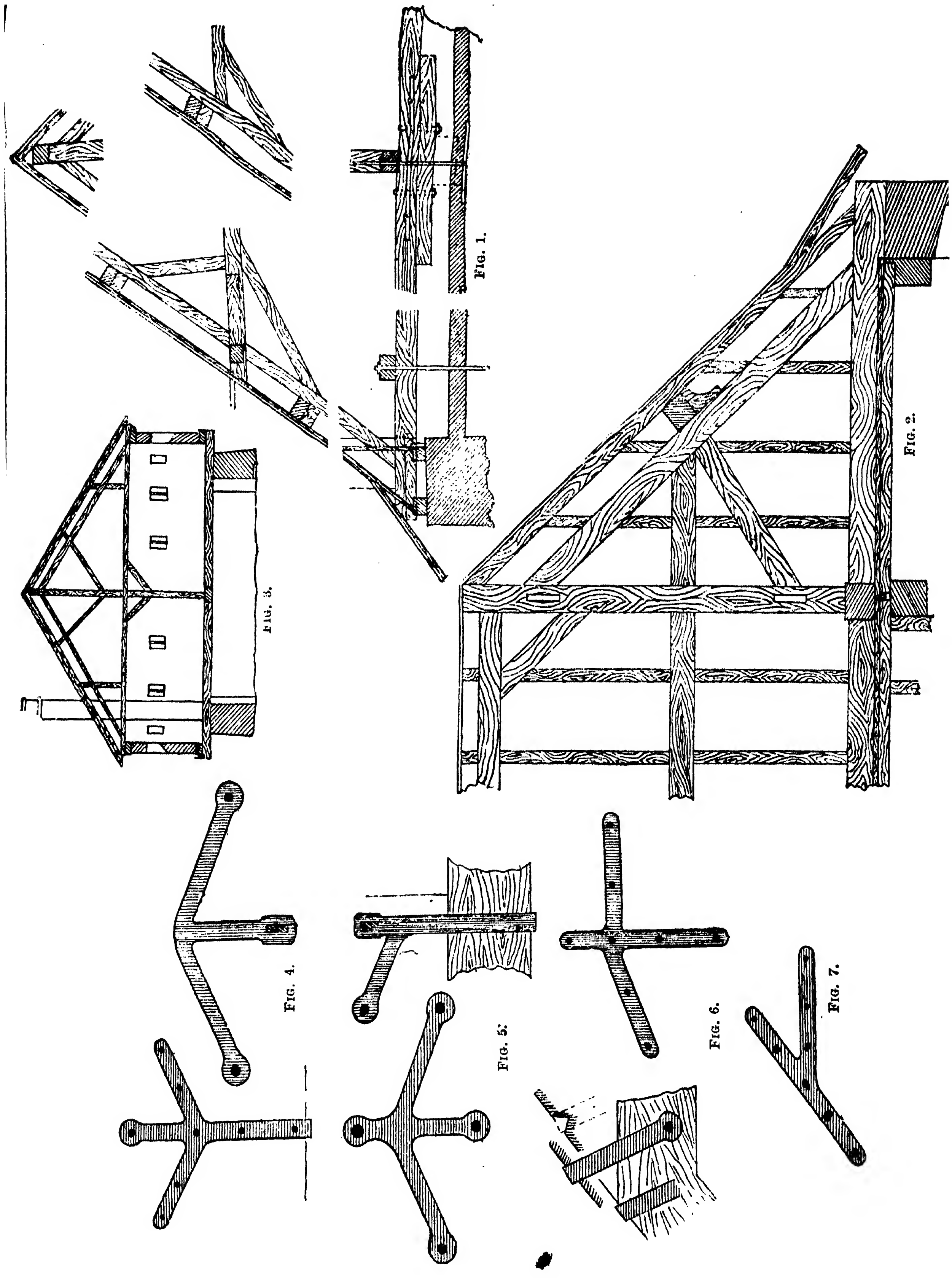


FIG. 1. FIG. 2. FIG. 3. FIG. 4. FIG. 5. FIG. 6. FIG. 7.

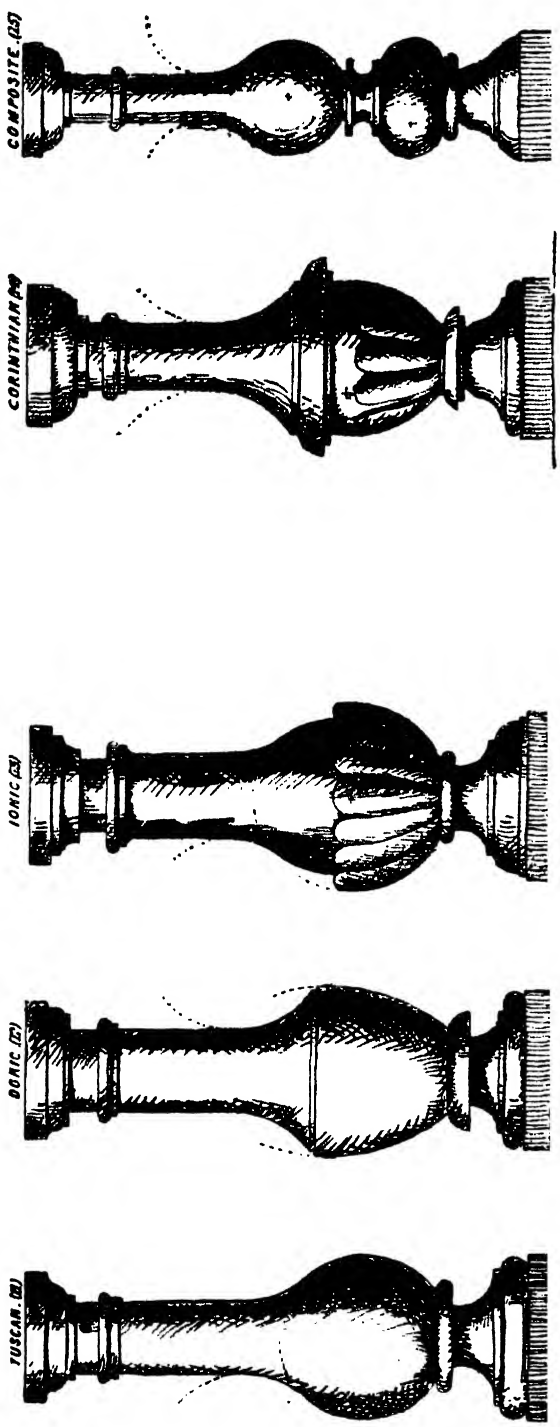


Fig. 4.

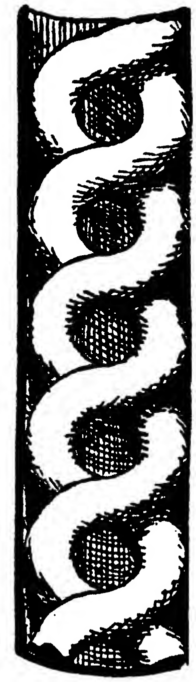
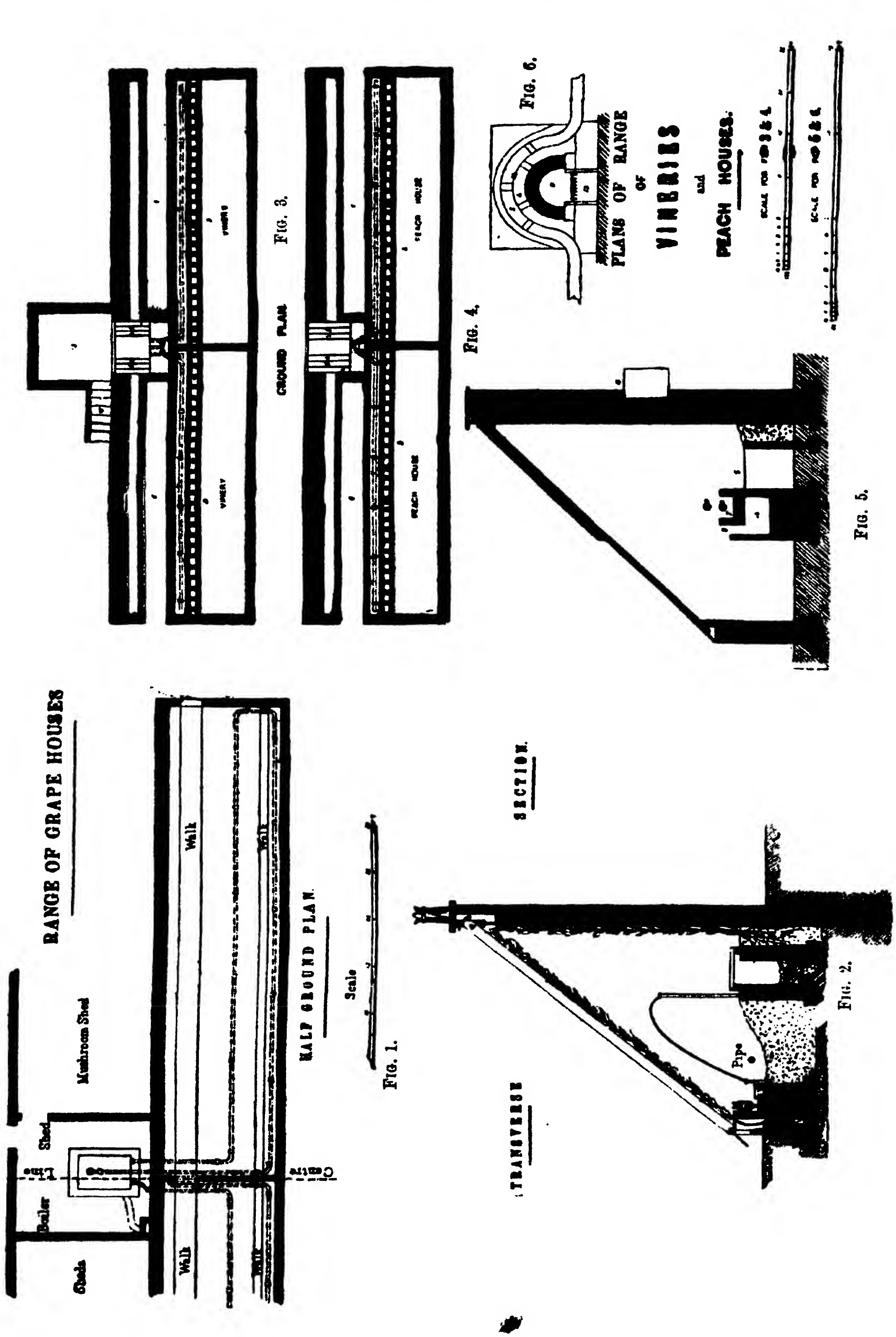
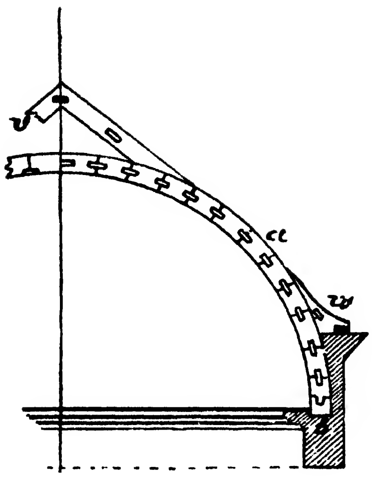


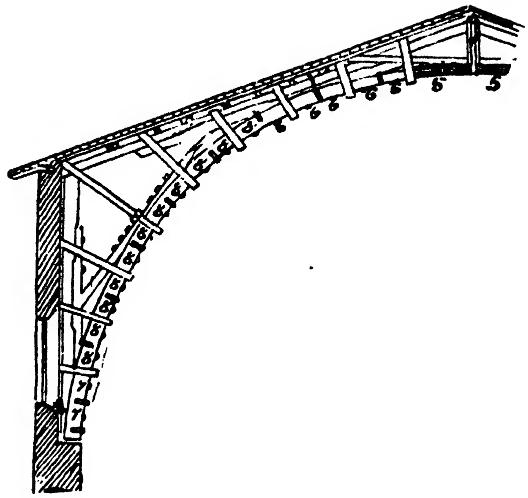
Fig. 7.

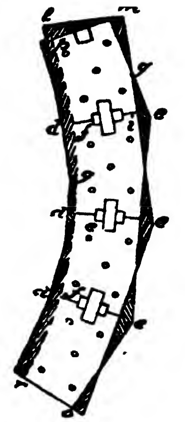
Fig. 6.



RANGE OF GRAPE HOUSES
HALF GROUND PLAN
Scale
Fig. 1.
Mushroom Shed
Shed
Boiler
Sheds
Walk
Centre Line
TRANSVERSE SECTION.
Pipe
Fig. 2.
Ground Plan
Fig. 3.
Vinery
Peach House
Fig. 4.
Fig. 5.
Fig. 6.
PLANS OF RANGE OF VINERIES and PEACH HOUSES.







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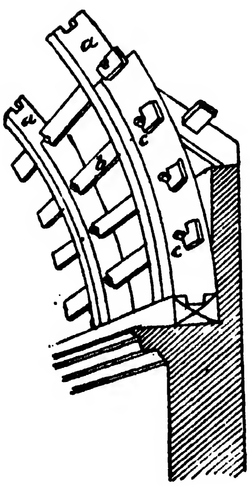

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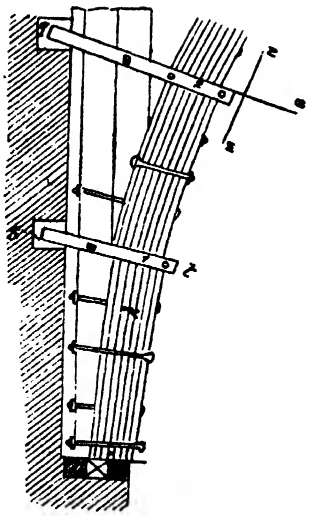

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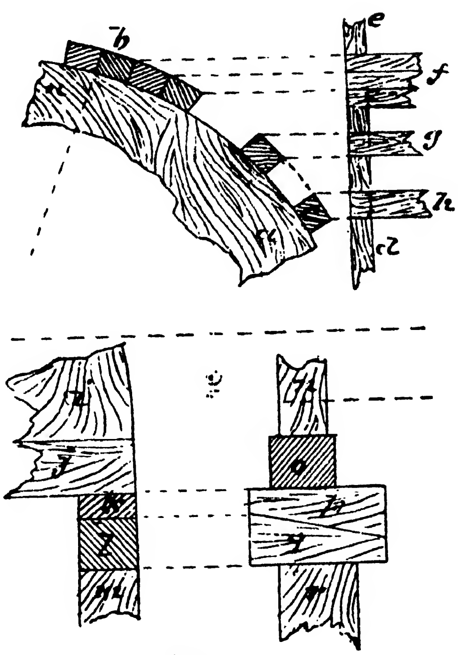

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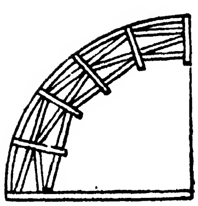
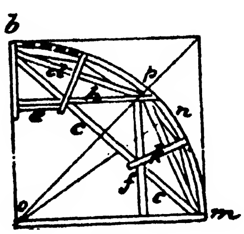


FIG. 7.



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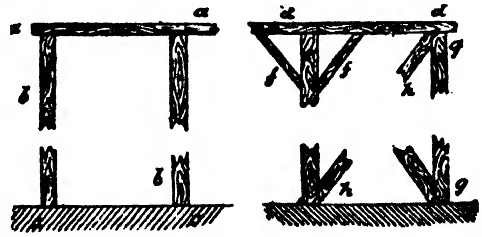

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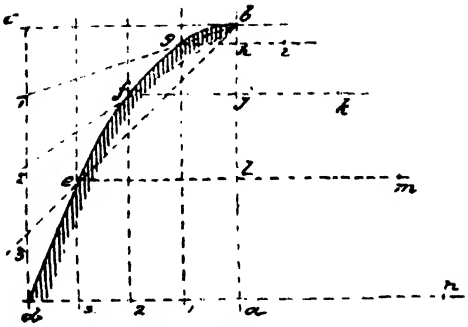
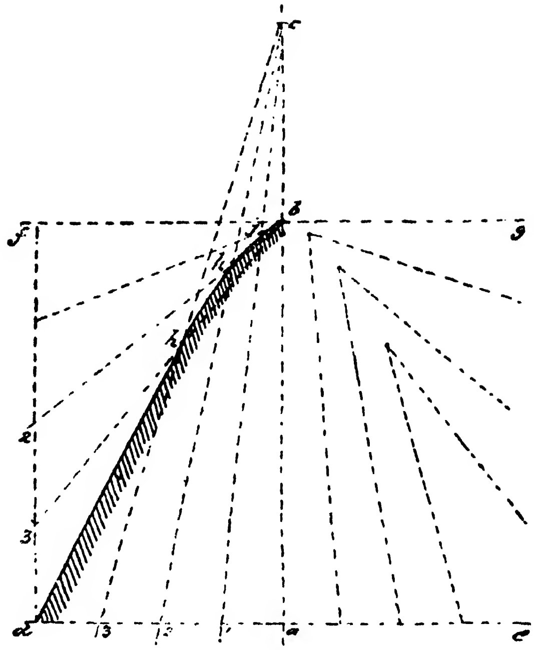


FIG. 1



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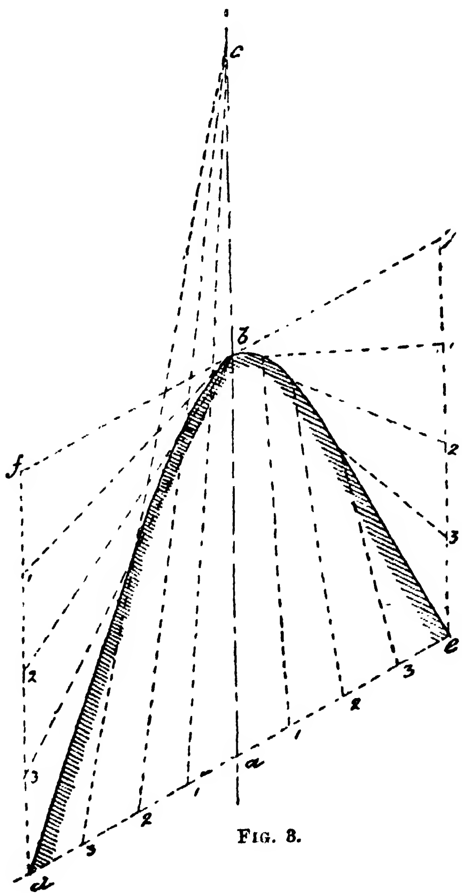

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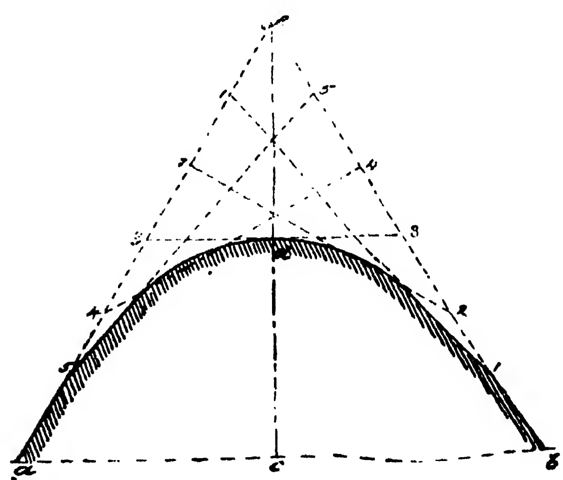


FIG. 4.

THE TECHNICAL STUDENT'S INTRODUCTION TO THE GENERAL PRINCIPLES OF MECHANICS.

LAWS AFFECTING NATURAL PHENOMENA—MATTER AND MOTION.

CHAPTER XXIX.

Changes in the Character of Motion brought about by Changes of Position or of Form in Bodies.

WE have seen, from what has been stated in the preceding paragraph, the important influence which form exerts in bodies moving along surfaces. It is no less noticeable in the case of bodies which move through the air or through water—or, conversely, which derive their motion from or are influenced by or acted upon by air or water. Thus, by a change in the form of a body which is projected or shot through the air, we bring about a very material change in the character of the motion of the body. And this change in the form may be of a very simple character; generally speaking, the change consists in adding to the general bulk of the object parts which, forming new surfaces, give

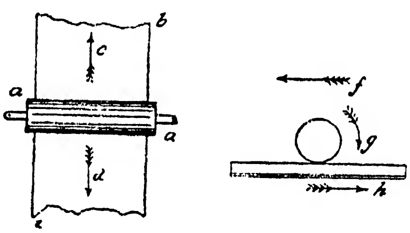


Fig. 33.

oblique ones—against which the air or the water impinges at an angle to the general lines of the object. When we come to consider the phenomena of bodies put in motion by more than one force, we shall illustrate this characteristic of motion—as the illustration will come more closely under that subject. We refer here to the point under notice only in a general way, instancing the feathers of an arrow shaft or the projections of a rifle bullet as examples. The student will find throughout his practice a wide variety of instances in which what we have called the "bias" of a body or object depends upon the form or configuration, and which we have illustrated in a number of ways. These examples have hitherto been confined to the cases of bodies or objects which have motion in themselves over surfaces which are fixed. But the phenomena are observable, although they are manifested in a different way, when the converse of this condition is met with, and we have the bodies or objects fixed or stationary and the surfaces which are in contact with them in motion; so also when the surfaces are fixed and the body or object moves in contact with these surfaces, but are so fixed that they move always in one position. We shall see presently that by the change of that position a change is in like manner brought about in the character of motion. Let us suppose that a roller, *a a*, fig. 33, is free to revolve in fixed or stationary bearings; its surfaces or periphery coming in close contact with the surface of a table, *b b*. This table has an alternate motion given to it, which causes it to move horizontally in the direction of the arrow *c*, and next in that of the arrow *d*. The motion of the roller *a a* will thus be that of alternate circular, as that of the table *b b* of alternate rectilineal motion—the roller, as *e*, revolving in the direction of the arrow when that of the table is as at *f*, and revolving as at *j* when the table moves as at *h*. Presuming that the work to be done by this mechanical arrangement is to rub out or mix some greasy substance, as paint, the young student might at first conclude that, taking care to have the two surfaces—that of the arrow *a* and the table *b b*—closely enough in contact, it would matter

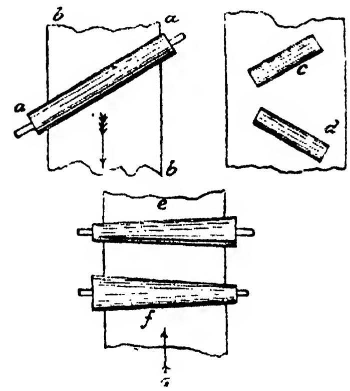


Fig. 34.

little, so far as the rubbing or mixing action was concerned, how the roller *a a* was placed in relation to the table *b b*. But, if he will think the matter out, he will perceive that the rubbing action will be different in character by placing the roller *a a*, as in fig. 34, oblique to the line of motion of the table *b b*. In a certain class of machines two or more rollers are placed oblique to each other and to the table, as at *c d* in the same figure; conical rollers are shown at *e f*. In many cases of mechanical work the value of this principle of placing bodies diagonally or obliquely in relation to motions of a rectilineal character is becoming more and more recognised, and late years have witnessed a variety of applications which may be said to add their mechanical efficiency to its adoption. The young reader may be helped in his analysis of the motion given in fig. 34, at *a b*, *c d*, by considering the character of that in fig. 35. This represents the principle of working of a farming implement for stirring up and disintegrating the soil, and may be looked upon as an

excavating machine. The roller *a a* is provided with a series of arms or claws, shown in diagram, projecting from its surface. Rotatory motion was communicated to these by appropriate mechanism, set in motion by the same power which dragged the apparatus along in the direction of the arrow *c*, and which direction was at right angles to the line or face of the soil to be stirred or excavated. While this to a certain extent was efficient in operation, it was found that in place of fixing the working shaft *a a* parallel to the face of the work or soil to be dug up or excavated, or at right angles to the line of direction of motion *c*, by fixing it diagonally in the framing, as at *d e*, the work was done much more readily and efficiently, the soil being more thoroughly disintegrated or broken up than when the motion at *a a* was used. The reader will perceive that the effect of this arrangement was to present the excavating shaft to the soil so that it took the work in parts or divisions, the end *d* entering the new soil in the first instance; and as the frame was dragged forward in the direction of the arrow *c*, the rest of

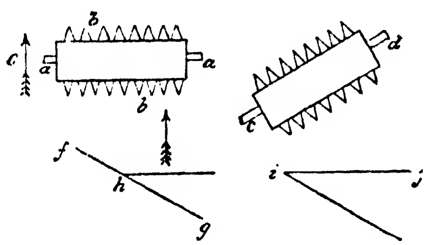


Fig. 35.

the rollers came gradually into action. But as the soil was operated upon by the claws near the end *d*, it was passed on in an angular or oblique direction, as shown by the line *f g* in the diagram, along the line of shaft, so that the claws towards the end *e* took it up and worked upon before they themselves were brought up to be in contact with the new soil, as at *h* in the diagram. By thus acting on the principle of "divide and conquer" it was found that not only was the soil much better broken up, but the power required was much less than when the whole of the claws or tines were brought at once to operate upon the full length of the line or face of new soil, as *i j* in the diagram.

Examples of Oblique Motion.

The same principle of oblique action is adopted with striking success in cutting machines. Thus, suppose *a a*, fig. 36, to be a thick mass made up of many sheets of paper, and this mass has to be divided across at a certain part, if the knife *b b* is so actuated by mechanical arrangements that it is brought down to *a a* in the direction of arrows *c*, *d*—that is, at right angles to the face of *a a*—great power would be required to force the knife *b b* through the mass of paper, and the severance would not be effected with what is called a "clean cut." But if a double motion could be given to the knife, so that while it descended in the direction of arrows *c*, *d*, it had a side or lateral motion in the direction of arrow *f* (see diagrams at *e f g*, *h i j*), then the "cut" would be a clean, that is, even, smooth-edged cut, while the power required would be much less than with the former arrangement. The accurate principle of giving a cutting knife a motion which is a compound of two other motions which are different in direction (see paragraphs in "The Boat and Ship Builder" on motion derived from two forces) is based on the assumption that the cutting edge of a knife, however keenly sharp, is not a uniform line, but is, on the contrary, made up of a series of small sharp-edged wedges. A microscopic examination of even the finest cutting edge of a surgical

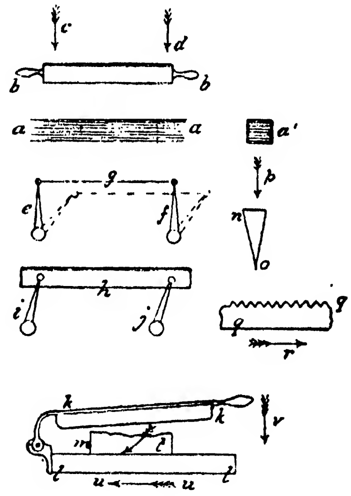


Fig. 36.

instrument shows the absolute accuracy of this assumption. A knife blade, as that used in a cutting mechanism, such as at *a b c d* in diagram, fig. 36, is in its cross section a wedge, the back edge being much thicker, as at *n* in the diagram, than at the cutting edge *o*, which is brought to the finest line possible. But if this were pressed down vertically, as in the direction of arrow *p*, it would indent or press in a soft surface opposed to it, but it would only be by great pressure that it would cut or be forced through the mass or body. But as the edge is really made up of a series of infinitely small wedges, as at *q q*, to make these effective in operation the knife blade—which we thus see to be a double wedge—must have a lateral motion, as in the direction of arrow *r*, in combination with the vertical, as at *p*. This dual motion is technically called the "draw cut," or "draw" motion. One method of obtaining this in the case of a cutting mechanism is shown in diagram, the knife *k k* being

gradually brought into contact with the mass of material, *m*, to be cut as it descends in the direction of arrow *t*. This well-known cutting appliance is much more efficient than one with a vertical cut, as at *c d* in fig. 36; but it would be still more efficient if, while the knife *k k* was descending and cutting through the mass *m*, the latter, or rather the table on which it rested, had a correspondingly regular movement in the direction of the arrow *u u*.

Diagonal Movements in Mechanism.

The value of diagonal or oblique positions is shown in mechanical arrangements in which the motion of fluids is concerned. Numerous illustrations of this are to be met with in practice, and several are given throughout the pages of this work. In fig. 37 we give two examples of it. In this *a a* shows a circular internal flue of a steam-engine boiler surrounded with water, through which flue the heated air and gases from the furnace pass, as in the direction of the arrow *b* in diagram plan. For long, steam-engine boilers were as a rule so constructed that the water was contained in the vessel in a large mass. The idea

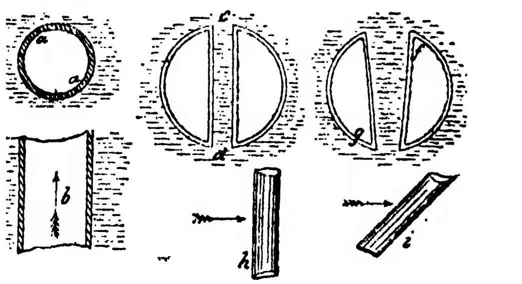


Fig. 37.

here illustrated, of dividing or splitting up, so to say, a large, heavy bulk of water to be heated into lighter masses and smaller bulks, has led to great improvements in boiler making and working. One of the earliest methods was that known as the Cornish boiler, in which one flue was placed internally, as at *a a* in the diagram, which obviously gave a large heating surface in what may be called the very heart of the mass of water. It occurred to some one that the principle of division of the mass of water and of increasing the heating surfaces with which that water came in contact might be productive of greater economy of heat, and consequently of fuel. This was at first proposed to be done in the case of the internally flued boiler, as at *a*, by connecting at intervals along the length of the flue its upper part, *c*, with its lower, *d*, by vertical tubes, one of which is shown at *e*. This still further divided the mass of water, and gave smaller portions to be heated at a time and larger heating surfaces. The plan was found to be in great measure efficient; but it was not till the happy idea occurred to some one to make the tubes conical, as at *f g*—that is, with angular or oblique sides or exterior surfaces—that the full efficiency of the system was secured. When this system was adapted to the internally flued boiler, one of the most efficient of all our boilers—the Lancashire, with "Galloway" tubes — was obtained; the conical tubes being so called from the name of the inventor, one of the firm of Messrs. Galloway & Co., engineers, of Manchester, who have done an enormous trade in the manufacture of boilers on the principle here described. The student will perceive that the conditions and the phenomena of the water moving within the tube, and the heated air playing on its surface without, would be different if the tube were reversed—that is, the narrow end, *g*, at the top in place of being at the bottom, as in the diagram; just as the phenomena would be different in the case of a tube through which water was circulating and on the exterior of which heated air was impinging when that tube was placed vertically, as at *h*, or obliquely, as at *i*. The observing reader will have many opportunities of noticing how much the motion and the phenomena of motion alike of solid and of fluid bodies are modified and influenced by conditions connected with form and position; and if to the points he observes he gives that which makes observation valuable—thought—he will in his practice be able to adapt what he learns to a much wider range of circumstances in work than he would at first sight be disposed to believe possible.

Circular Motion.—General Considerations.

The change in the condition of bodies in bringing about a change in the character of the movements or motions which a given force imparts to it, is that which gives the power to the machinist to do a variety of work or to bring about certain effects. And this principle, which affects more or less all mechanical arrangements, is just as strikingly exemplified in the case of cylindrical bodies as in that of any other. Known perhaps more widely as "rollers," these bodies play one of the most important parts in our industrial mechanism. Simple as a "roller" looks—so simple that to the popular mind it is scarcely considered as a mechanical body at all—its use in and adaptation to industrial work as performed by the use of machinery, to the large, and in some cases the complete, exclusion of manual labour, save that only required to supply the material to the machine and keep it in operation, has completely revolutionised certain branches of trade. Without the use of the roller none of our textile manufactures, as carried on now almost exclusively by the use of machines, would occupy the position they do, producing textile fabrics literally by the mile in periods of time during which in the olden times hand labour could not have produced many yards. And, simple as this element of

mechanism is, it may safely be said that it took centuries of human experience in the work of everyday life before that experience led man to the conception of the roller. Its principle, indeed, lies at the root of circular or "curved-line" motion, as opposed to or quite different in its character from that of straight, or what we call "rectilineal or right-line" motion. And how very long it was before the mind of man was able to grasp the conception of circular motion, his history gives us some fair idea. It may safely be said that it took many generations of working experience to enable man to comprehend the possibilities of circular motion as a potent help to him in the doing of his work, wherever that work was aided by what are now called mechanical contrivances. This conception of circular motion, when once grasped by the mind of man, gave him a power which it took nevertheless long years to avail himself of to any great practical and useful purposes, and which took still longer for it to enable him to have a right conception of its mechanical possibilities, carrying with it as it did one of the powers which have made modern mechanism what it is,—for without circular motion not a tithe of it would or could exist or do work. One is but too apt to overlook the vast importance of this principle simply because it is, or to put it correctly, appears to be, a little thing, a trifle. So also in many other of the directions to which the youthful student in mechanism may give thought we shall find exemplifications of the value of little things. How many, for example, make and use that most familiar of all mechanical appliances, a "screw bolt" with its accompanying "nut"! Think of it, what it really is—a mechanical contrivance so simple, yet so powerfully effective, and adaptable to so infinitely wide a range of circumstances, that had it not been invented when it was mechanical progress would have been retarded for an unknown period. Progress without it, indeed, was simply impossible; for this mechanical contrivance, so trifling, was indispensable, and without it circular motion, with all its mechanical potentialities, would also have remained but a dream, another addition to the long list of philosophic toys or playthings. Detailed illustrations and descriptions of circular motion, what it can do and what it has done, are not here necessary; this work, in every one of the wide range of machines and mechanism which it illustrates, gives in the aggregate an almost endless variety of illustrations of its value. Our object chiefly in this paragraph has been to point out to the youthful student how it took a long period in his history for man to grasp the conception of, and almost as long a period for him to work out into practical shape, so simple and trifling a thing as but too many conceive circular motion to be; and from his direction given to the thought of the student on this point our aim has been, as it is our hope, that he will derive a lesson which he will find to be of essential value to him in his practice yet to come, which if it be guided by careful thought given to every detail, however minute, to every part, however trifling it may to the common mind appear to be, will be certain to be a successful practice. We have elsewhere in this section pointed out to the student the value of the habit of "observation,"—and engineering has been called the "science of observing,"—but if we were asked upon what depended the future of mechanical progress, we should unhesitatingly reply the habit of thinking every subject or piece of work completely out, "all round," as the common expression goes. And this does not do away with or lessen in any way the value of the habit of observation—rather enforces this, for in truth observation, to be worth anything, must be thoughtful observing, so that it cannot exist without the habit of thinking.

As a rule, all bodies which have a circular motion, or what is called movement or motion round an axis or central point, are circular in form—that is, have their peripheries or bounding lines curved in the form of a circle the centre of which is in the centre of the axis of motion. A very little consideration of the general circumstances under which motion is acquired and required will show the reason for this, of which an endless series of examples are found in the practice. There are but few exceptions to this rule dictating the form or configuration of rotating bodies—the elliptical and the diagonal-square toothed wheels being the chief, and these being adopted in order to produce certain changes in motion of parts of machines. The most familiar illustration of a circular body is a grindstone, and as turned by manual labour it affords a good example of circular motion in which its phenomena are displayed, and a striking instance of what appears to be a very simple, but what is indeed so important an element in practical mechanism that its value cannot be overestimated. Reference is here specially made to the crank, or as it is usually termed the handle, by which the muscular force of the man working the grindstone communicates to its mass a motion of rotation, or causes it to revolve, or in common language to turn round. So very familiar have we become through long usage of this simple contrivance (and which, like all perfect—so called—contrivances, is the more valuable because of its simplicity), that we generally have ceased to recognise in it one of those inventions of man which have given him, so to say, a power which has positively revolutionised his material existence, inasmuch as it has enabled him to perform a vast variety of work—mechanical operations—which without it could not have been done at all.

THE CARPENTER AND HIS TECHNICAL WORK.

Its Origin and Early Work—The Principles and Details of its Practice.

CHAPTER XV.

At the end of last chapter (vol. iii. p. 154) we stated that it is practically very difficult to make grooves with such precision that no spaces will be left between them. Yet it is evident that if the grooves are not firmly fastened together we shall not obtain the desired effect. To obviate this difficulty we have recourse to keys or square trenails made of hard wood, driven firmly between the grooves, as we have already seen illustrated in fig. 4, Plate XIX., and as shown in fig. 73.

As the resistance of wood is much greater according to its length, we have recourse to another kind of iron brace, which consists in strengthening the beam by means of two pieces, as *a* and *b* (fig. 78). These

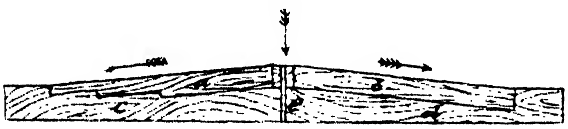


Fig. 78.

two pieces have the tendency to swerve or bend from the straight line in consequence of the weight which they bear, and consequently divert or change the pressure in the direction of the length of the beam *c d*, as shown by the arrows. The illustration shows two ways of joining the pieces *a*, *b*, to the beam *c* by means of one or more scarfs, as at the piece *a*. The two pieces butt at the upper ends, and are united by an iron hoop or band *e*, as shown.

Fig. 79 is also composed of two pieces, *a* and *b*; but

Fig. 79.

these are separated by a horizontal piece, *h*, to avoid giving too great a height in the middle of the beam. *p*, *p*, are bands or hoops of iron binding the whole.

In fig. 80 the upper part of the beam is cut in a

Fig. 80.

curve, so as to make the ends only two-thirds of the height of the middle; then, upon this first piece is placed a second, which is bent by means of bands of iron, *l l*, in such a way as to make all the parts of the beam join exactly. This arrangement very nearly doubles the strength of the piece.

In another method of building beams the two pieces have grooves cut across their faces into which keys are driven, and the whole secured by iron hoops. In fig. 81 we illustrate a method of forming an exceedingly strong beam out of thin planks or deals. It is generally employed in the formation of curved rafters for roofs of large span; the planks are placed in contact with each other, as shown at *a b c d e f*, in fig. 81, and care must be taken that they "break joint"—that is, that the joint of any two contiguous pieces, as the joint *m*, shall butt against or be placed at the solid parts, as *n* and *p*, of the pieces *o o* and *q q*. This may be taken as a section on a larger scale of assemblage in figure above on the line *g h*. The diagram then further illustrates the system of "breaking joint"; the joints *k* and *l* butting against the solid parts of the central piece *j*. When we come to the consideration of roof framing we shall further illustrate the methods employed of forming built beams for the curved rafters of roofs of large span—

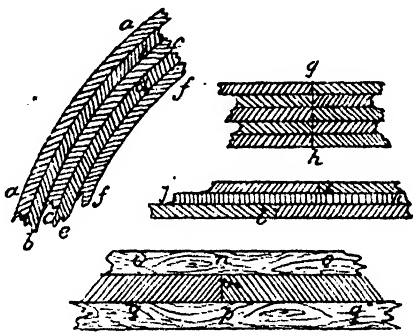


Fig. 81.

proceeding now to the consideration of the second method of strengthening beams by the employment of the principle of "trussing." Some of the methods of scarfing of beams already illustrated may be taken as examples of built beams.

Framing.—Beams in Framework.

When a beam of any length, as *a a*, fig. 82, is placed to cross or span a void space, as between two walls, *b b*, a weight acting at *c*, or distributed along its whole surface, or even the weight of the beam itself, gives the beam a tendency to fall down in the centre, as shown at *f g* in the beam *e f g*. If the weight acts entirely at the centre, as in the direction of the arrow *d*, the tendency of the beam to bend is at its greatest. Hence, in all framing the object of the designer is to distribute the weight over the whole beam as uniformly as possible. Thus weighted, so to say, a beam can support or carry a much heavier weight than when loaded at the centre. How much and in what way pressures act upon beams, and how they are calculated, will be fully discussed when we

come to consider the principles of framing. The bending of a beam is technically called its "deflection." As we have said, all beams have a tendency to deflect; and of course the more carefully calculated and constructed, the less will be the amount of deflection. To provide for the deflection, beams when of wrought iron or steel are made purposely with a bend in the opposite direction, as in the diagram *i i*; so that when placed *in situ*, and the pressure brought to bear on its upper surface, as in the direction of the arrow *h*, the deflection brings the beam down to its proper level line, as *i i*. The amount of opposite flexure or curvature given to a beam thus is called its "camber."

The two principal strains to which materials are exposed in all framework are tensile and transverse or cross strains or pressures. A tensile strain has a tendency in a timber beam to tear its fibres apart in the direction of the length of the beam; a transverse or cross strain or pressure has a tendency to

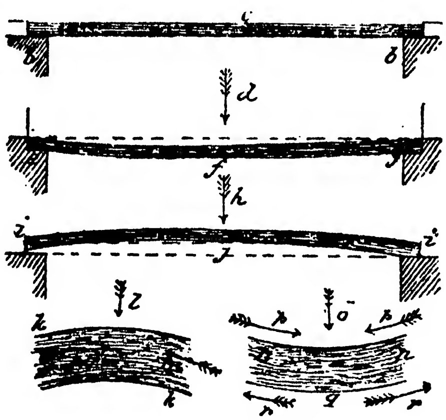


Fig. 82.

break it across in the direction of its breadth. A tensile strain may be popularly described as a pulling, a cross or transverse as a pushing strain. The strain known as that of "compression" is that which tends to squeeze or force the fibres together, and may so disturb them as to cause a beam, as a vertical column of timber, to bulge out at one part, and thus be broken. A beam placed under such circumstances, as *a a b b c*, fig. 82, with a "distributed" load at upper side, or a single pressure acting at centre *c*, is placed under two distinct strains under the deflection. Thus let *h* in fig. 82 represent the central part of the beam *a a*, deflected by a heavy weight or pressure at *c* in upper diagram; this deflection, shown in an exaggerated manner, gives a concavity to the upper side and a convexity to the lower. Under those circumstances the fibres on the top side are placed under compression, tending to force or (to use the popular term) squeeze them together in the direction of the arrows *p*, *p*, towards the centre. On the under or convex side, *q*, of the beam, the fibres are, on the contrary, pulled or extended outwards, as in the direction of the arrows *r*, *r*, from the centre *q*. The fibres are here thus put under a tensile strain. The combination of the two strains—that of compression (known also as "compressile" or "crushing") at the top surface, *p p*, and of tension ("tensile" strain) at bottom, *r r*—if carried far enough, will break the beam. The youthful reader is recommended to take a thin strip of wood and bend it round: he will, by carefully examining the effect of the strain or pressure thus put on it, have a fair idea of how the two strains act. The effects we have just described are precisely of the opposite character in a beam deflected or bent in the opposite direction, as at *k k l* in fig. 94. The fibres on lower side are those which are under compression; those of the upper under tension. Beams of timber are better calculated to resist strains of compression than of tension; and the "trussing" of beams, as this work is called, has for its principal object the providing against the tensile strain to which it may be subjected.

Framing.—Strengthening of Beams.

If the reader will remember what we have said as to the tendency of all loaded beams to deflect or bend downwards in their centre—a result also of beams of considerable length, the weight of the materials alone acting at a distance from the supports—and what are the results of these strains upon the fibres of the wood, he will see how one method adopted in some cases of strengthening a beam by enabling it to resist the strains brought into existence in a deflected beam, or calculated to increase the deflection, meets the necessities of the case. The method consists in cutting out grooves in the upper side of the beam, and filling them in with wedges or keys of a very hard wood, as at *g g*, fig. 1, Plate CLIII. The effect of this arrangement is illustrated in the upper diagram in the figure. If a triangular-shaped groove, *a*, is cut out across the face of a beam, *b b*, before it is placed in position, when so placed the pressure put upon it causes deflection; and from what has been said in connection with diagram *p p q*, in fig. 82, the groove *a*, in fig. 1, Plate CLIII., will be closed either partially or wholly according to the degree of pressure, this acting in the direction of the arrows *c*, *c*. But by driving in a wedge of hard wood, as at *d*, the pressures still acting in the direction of the arrows *e*, *f*, will be resisted; and the harder the wood of *d*, and the more the pressure of *e f* resisted, the less tendency will there be in the beam to deflect, as at *f* or *q* in fig. 82; and thus the tendency of the pressure to put the fibres of the under side, as *q*, under the strain of tension will be prevented at the point where their action is greatest—and which strain of tension we have seen that timber is least calculated to resist.

Of all materials used in construction, wrought iron is the best calculated to resist tension or tensile strains, cast iron to resist compressive or crushing forces. These two materials, therefore, we find, have been largely used in the trussing of beams. Thus the wedge *d*, or the keys or filling-in pieces *g g*, of hard wood in fig. 1, Plate CLIII., are, as we have seen, put under a strain of compression or crushing; but by substituting for wood cast iron, we obtain a material much better fitted to resist compression than oak or other hard wood employed in construction. If cast iron be used, it is the best way to employ it as a plate let into a recess cut in the upper side of the beam near its centre. This is partly seen at *h* in the beam *i i*, fig. 1, Plate CLIII. Fig. 6, Plate CLIII., illustrates methods of securing the cast-iron plate used as at *h* in fig. 1, Plate CLIII. This may be done either by bolts and nuts, as at *q q*, *r s*, shown in detail in section at *f g h i*; or, to obviate such weakening of the beam as bolt-holes might cause, the plate may be secured to the beam by bands or hoops of wrought iron, as *a b c d*—in side elevation at *e e*—and "shrunk on" while hot; or the hoop may be made in split hoop, as at *k k*, brought together when passed over the beam, and secured by the small binding bolt and nut *m l*. To secure the full effect of the cast-iron plate, it should be let into the upper side of beam, as at *q q*—not merely laid on the surface, as at *n n*—as the strain in this case is brought chiefly on the bolts or hoops; whereas by the method shown at *q q r s* the strain is brought chiefly upon the beam in the direction in which it is strongest, and partly only upon the bolts or hoops.

Some years ago the Society of Arts awarded a prize to a Mr. Smart for an improved method of strengthening a beam on the principle of compression, as illustrated at *d* in fig. 1, Plate CLIII. In the beam *a a*, fig. 3, Plate CLIII., a narrow part is cut out, or a thick saw draught is made, as at *b b*, and near the end of the beam a triangular or wedge-shaped part, as *c*, is cut out, to a certain depth across the upper face or edge of the beam. This is done at both ends; and the part *b* extends along nearly the whole length, stopping short at some distance from the parts cut out, as at *c*. The beam is thus partly divided into two in the direction of its width or thickness. In the centre of the upper part *d* a piece is cut out. This is of width sufficient to admit a hard-wood wedge of the form as shown in section at *a*, in fig. 2, Plate CLIII., or it may be made of cast iron. Before this is inserted, the upper parts, as *d*, fig. 3, same Plate, are lifted up. This can be done without breaking them off from the lower part, as *a a*, inasmuch as the open grooves at *c* close from the compression of the fibres in the direction of the arrow *f*. When fully lifted the parts cut out at *c* close up, with the block *a*, fig. 2, Plate CLIII., inserted. This makes the beam assume the form shown in the figure, the upper part, *b b*, being separated from lower, *c c*, by the triangular opening *d d*. We look upon this principle of strengthening beams as capable of being adopted with useful effect in a wide variety of work. A modification of the method illustrated in fig. 1, Plate CLIII., at *d*, is shown in fig. 4, same Plate. In this a saw draught is cut out across the upper face of the beam, and it is then bent upwards till the saw draught opens, assuming the form of a triangular opening. Into this the block of hard wood or of cast iron, *a*, is inserted, when the pressure keeps this tight. By this arrangement a small beam may be made capable of bearing a much greater weight than it would do in its original form. So also is this the case when the beam is treated as in fig. 5, Plate CLIII. In this the saw draught or piece cut out, as at *b b* in fig. 2, Plate CLIII., extends to very nearly the ends of the beam, and is there strengthened by iron hoops, as at *a*. The two parts, as *b b*, *a a*, are then opened and extended, and two wedge-shaped blocks, as at *d e*, but in reversed position, are inserted. This is a modification of the method illustrated in fig. 2, Plate CLIII.

We have just said that wrought iron is admirably fitted to resist tensile or pulling strains, and that advantage is taken of it in trussing beams to strengthen them. The simplest way is to secure a plate of wrought iron, as *j*, fig. 1, Plate CLIII., to the under side of the beam *k*; but, although this is a position well fitted to resist those tensile strains at the under side of the beam to which all beams are more or less subjected—even a beam supporting, as we have seen, only its own weight—yet this method has obviously its inconveniences, and another is preferred in practice. This is illustrated in fig. 7, Plate CLIII., and which represents in diagram what is called a "flitched" or "sandwich" beam. The derivation of these names, especially the latter, is obvious enough, as they indicate that a plate of wrought iron is placed between two wood or timber beams, and the whole bolted together. The top diagram illustrates the whole beam, *a b*, as thus flitched in elevation; the centre diagram one of the beams—the off one, *c d*—with the wrought-iron plate shown in lines. The lower diagram is a plan of top as looking down upon the whole beam, *e f* being the off beam, *g h* the near one, with the plate of wrought iron between them. In fig. 1, Plate XCVI., the upper diagrams show in detail the method of flitching a beam, *i* and *j* being the two beams at the end, with the "sandwich" or "flitch" of wrought-iron plate, *k*, secured by the bolt and nut at *l m* passing through the whole. Bolts and nuts are in this case passed through the central part of the beams and flitch, as at *n a p q*, not merely at the ends, as in *a* and *b*, fig. 7, Plate CLIII.

THE WORKMAN AS A TECHNICAL STUDENT.

How to Study and What to Study.

CHAPTER XII.

Good Memory—Value to the Technical Student—Can be cultivated.

As with the habit of cultivating the faculty of observation, referred to at end of preceding chapter, so also with the cultivation of the memory. The value of a good one cannot be overestimated; it is to all men priceless, specially so to the technical man. A gift so gracious in its results is, therefore, worth having; and, like other gifts and graces, it can be cultivated. Nothing but weeds will grow—at least, flourish—in a neglected soil; you cannot expect to gain from this a harvest of useful produce, which "gives seed to the sower and bread to the eater," till you put the seed in, and carefully tend the plants which spring from it. So with the memory: it can be cultivated; and the facts of observation may be likened to the seeds of the good crop. You have the soil—the memory; it rests with you whether you allow it to produce weeds only, or corn. But as there are bad and good soils,—for all soils are not alike,—so there are good and bad memories. But as the bad soil can be made good by care, so also the memory. And the student will do well to give no credence to the statement that this cannot be done, any more than to the assertion that a soil cannot be so improved that it will bear flowers and fruit where it now produces but grass and the rankest of weeds —a fact of which your common sense tells you the truth. And you have much encouragement given you in this effort at cultivation of those habits essential to success in life. No better illustration of what may be done by patient care can be given, than is seen in the treatment nowadays of the deaf and dumb, or, more properly speaking, the deaf mutes—that is, those who do not speak, being dumb, not because they cannot speak, but simply because they cannot hear. They have the organs of speech—that is, they *can* give forth the sounds which form words; only they have never heard, and never can *hear* these words as uttered by those who can both hear and speak. Yet, by a process or system of teaching, it may, and no doubt will, surprise some of our readers to learn that "deaf mutes, as they are called, can now be made to speak." The details of this system are exceedingly curious, and afford a striking evidence of what man can do, if only he wills it, in ameliorating the sad condition of many of his fellow-men. These details are out of place here; and we only refer to the system by way of illustration of the fact that if so much can be done by patient care, no less than by skill, in a case where we might reasonably enough, arguing from the circumstances of deaf mutes, as they exist, decide that little, indeed nothing, could be done, surely a good deal can be done in improving habits and faculties in students and workmen which exist, although not of a high order. They can be made higher—that is, of greater practical value—by cultivation; and we maintain that in the interests of society, assuredly in their own interests, this cultivation is a duty. When we make greater progress in technical education we shall find that amongst technical workmen it will, as a rule, be esteemed to be a privilege.

All these, and such-like considerations which may yet be presented to the reader, must not be looked upon by him as if they did not concern him. It is impossible to overrate their importance, for on them and their application depends the fact of their technical education being carried out and completed in a way practically valuable. We use the term completed here, but only in its true and limited sense; for the truth is, that no man's education is ever fully completed. He is always learning, but it may with all safety be said that the aptest and the most willing pupils in the school of daily life and experience are those who, from the eminence of their position and the extent of their knowledge, might be supposed neither to require anything further in the way of, nor to feel the necessity for it. So true is it that it is only the ignorant who claim to know so much. So true also the paradox afforded by the statement of the philosopher, who, being congratulated upon knowing so much, replied that the more he knew, the more he knew how little in reality he did know.

The Technical Student in Relation to his Moral Faculties.

In the preceding paragraphs much has been given on the subject of the "how" to study, in which we have endeavoured to show that the question or problem of technical education is to be solved mainly by the student himself, and this on the supposition that he formed one of a "class" or school under the guidance of a competent teacher. For the teacher, however able, can only give of what he has himself acquired, what the pupil or student is willing or, as it may be, able to receive. A small vessel cannot possibly receive and contain the same contents as a large one; it can only receive up to the full measure of its cubical capacity. Yet both may be full, the small as well as the large. But the filling, so to say, in this case of education, depends, as we have said, greatly upon the student himself. No doubt, the teacher can aid him very much by educing or leading out his faculties or capabilities of learning, and by cultivating greatly increase them. A foreseeing teacher, and one well acquainted with human nature, will, indeed, by study of his pupil, be able to decide as to what "manner of man he is"—*i.e.*, of what he is capable in the way of the work of study; and he

may now and then point out powers hitherto latent, and this with all the startling effect of an unexpected discovery. And it will indeed only be that we shall find technical education take that great stride forward, for which every one is so earnestly looking, when teachers exercise their knowledge of human nature by which they will be enabled to take advantage of all the capacities and capabilities of their students, treating and using them as whole men, so to say; not attempting only, as is so often attempted now, to get work done by half tools only in place of complete ones. What we have already said on this point should, however, have made it very clear, and shown, or at least tended to show, what we have maintained to be the indubitably correct position—namely, that education will not be made complete, never rapidly—assuredly not certainly—secured, unless *all* the influences which go to make up the "man" are made available in its work. And the sooner the notion is got rid of the better, that some of those influences—among which range what some are pleased to designate as moral faculties, and only such—are therefore of no account in intellectual work and training, so also the sooner many of the difficulties at present attendant upon the carrying out of technical education, or rather, as they may be called, the attempts made to secure it, will vanish, or greatly so. Call them what you will, moral faculties or by any other name, the fact remains that they exist in every man in a more or less fully developed state; and existing, they exercise, whether we like it or not, a powerful influence upon what the man can or will do in any work he undertakes. And seeing this, it is but the purest folly to ignore these influences, and while still admitting that they exist, refuse to avail oneself of them. If by appealing to, and bringing into action, some of those so-called moral faculties, I can get my pupil to become all the more earnest and anxious conscientiously to do his best in acquiring knowledge, am I to be debarred from availing myself of this power by some fine wire-drawn considerations, so to call them, that such a power comes only within the domain of the moralist, or say the preacher, and not within that of the teacher? What, may it be asked, is teaching which is designed to raise the status of a man but placing him under a moral power? What little we do in teaching is done simply in virtue of what power it possesses as a mental agency; without it, teaching would do nothing. As this all too popular notion, that the teacher has nothing to do with what are called the moral faculties, is a bugbear, as it assuredly is, standing much in the way of progress, why should it not be got rid of at once? If it would please some tender minds, cease to call them moral; consider them only as purely intellectual faculties, or say as powers, no matter what they may be called, which can be made highly useful in the work of technical education.

The Results of Instruction largely dependent upon the Student himself when under the Guidance of a Teacher; wholly dependent when he is going through a Course of Self-Education.

But if this education is, as we have shown, and as we shall yet more fully see, mainly dependent upon the student, even when he is under the guidance of an able teacher, obviously he is wholly dependent upon himself when he is a self-taught student. Here, having only books and what he picks up through the agency of observation or intercourse with educated men to refer to, everything depends upon the way he avails himself of these sources of knowledge. And it is abundantly clear that his progress will be dependent upon, and influenced by, what discipline he puts himself under. To help him in deciding upon the points of this discipline, and how, after deciding upon these, he can best carry it out, we proceed to give the following remarks. And they will also be more or less applicable to his course of study, should that be carried out under the guidance of a competent teacher.

Many of the Points connected with the "How" mixed up with the Consideration of those relating to the "What" to Study.

We have said that we have already given much upon the "how" to study in this same point of discipline; and what yet remains to be said upon it will best be given in considering the "what" to study, to which, therefore, we proceed. And here we must note, by way of a saving clause, that we cannot possibly find space sufficiently wide to embrace all the subjects of study which concern the various branches of technical work. To treat the subject so comprehensively as this would obviously require so much space as would seriously interfere with that which is as clearly demanded in other interests as important in their respective degrees as this. Hence this exhaustive treatment is not here required at our hands; we shall meet, and we trust efficiently so, the necessities of the case, if we take some of the leading subjects of technical education, and point out some of the peculiarities as affecting their study and ready acquirement by the learner. Much, indeed, that we have to say comes under the head of "how to study," on which we have already said somewhat. It is in one sense not an easy thing to separate the "how" from the "what" to study; and after having given remarks in the preceding paragraphs on what may be called the leading features of the question of the "how," it will be found that a goodly number of its details are mixed up, so to say, with the subject of the "what" to study—so dependent upon each other are the two departments.

THE BRICKLAYER OR BRICKSETTER.

THE PRINCIPLES AND PRACTICAL DETAILS OF HIS WORK.

CHAPTER XIV.

RESUMING our description of diagonal brickwork, we take notice that it is in the second and third courses that the diagonal bricks are used, the one course lying at one, the next course at another angle; the

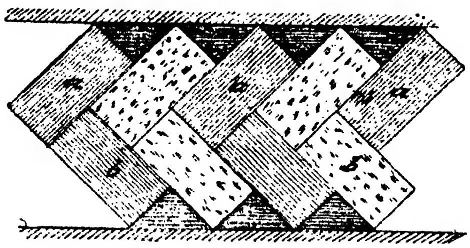


Fig. 39.

fourth course being a repetition of the first as regards the bricks in number, but reversed in position: if a row of stretchers be used along with three rows of headers—that is, if the first course has the stretcher in the front face of wall—in the fourth course these will be placed at the back. Fig. 39 illustrates in diagram fashion a course of two rows of bricks diagonally set. All these changes in position in this class of bricklaying, as in all other classes, is to secure what is the aim of every good bricklayer—as perfect a "bond" as possible.

When two rows of diagonally placed bricks are used in the same course of a wall, the bricks in each row are so arranged that the two rows lie in opposite directions. This class of bond is that known as "herring-bone" bond. The diagram in fig. 39 illustrates the way in which the two rows are placed at

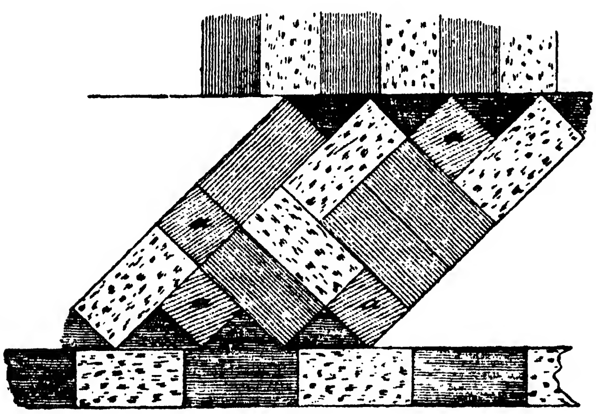


Fig. 40.

opposite angles—*a a*, for example, laying from left to right, *b b* from right to left. The angle, as in diagonal work, varies according to circumstances, and "bats" are in some instances necessary to make the rows complete. The arrangement of the two rows in the figure is symmetrical or regular, but an arrangement of what may be called irregular herring-bone bond is shown in fig. 40: in this bats or half-bricks are used to make up the bond.

There are other varieties of bonds in use in connection with solid or ordinary walls; a very common form is that known as "garden wall bond." This is illustrated in fig. 41, showing that each course is the same as the one above and below it, and each course is made of the same arrangement of bricks—namely, three stretchers, as *a a'*, *b b'*, *c c'*, and one header, as *d d'*, this being carried on throughout the course. Fig. 42 shows two methods of starting and finishing the courses at the ends of the wall. In diagram A the first course is begun with a "header" *a* and a "closer" *b*; the second begins with a "stretcher" *c*, next a "header" *d*; then follows the regular arrangement, three stretchers and a header, and so on. In diagram B the first course begins with the three stretchers *e*, *f*, and *g*, the next being a header. The second course begins with a "closer," *h*, then follow on three

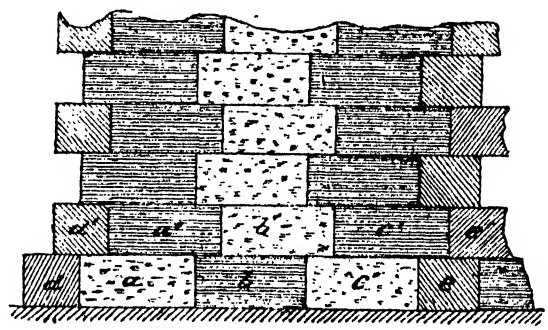


Fig. 41.

stretchers and a header, and so on to the end of the course, the last brick in which is a "closer," as at *h*.

So far as the face or the look of a wall built in different kinds of bonds is concerned, one bond may be taken to be as good as another. The general public, at all events, form no conception of what the peculiarity of the bond is—if indeed, as is more than probable is the true state of the case with a vast majority, they have any idea that there is more than one kind of brick-setting. Even as regards the usually adopted bonds, the "Flemish" and the "Old English," it takes some practice to enable students to tell at once whether a wall is built in the one bond or the other; and "experts" only can tell at the first glance whether neither the one nor the other is used, but some other variety. We might, if space permitted, give illustrations of not a few other varieties than those we have given, but our object will be served if to those we add the bond illustrated in fig. 43, in which the wall begun in "Old English" bond in the first two courses, as *a a*, *b b*, has four courses of stretchers, as *c c*, *d d*, *e e*, *f f*, the next two

courses being repetitions of the first two, *a a* and *b b*, these followed by four more rows of stretchers, and so on till the desired height is reached. If we suppose

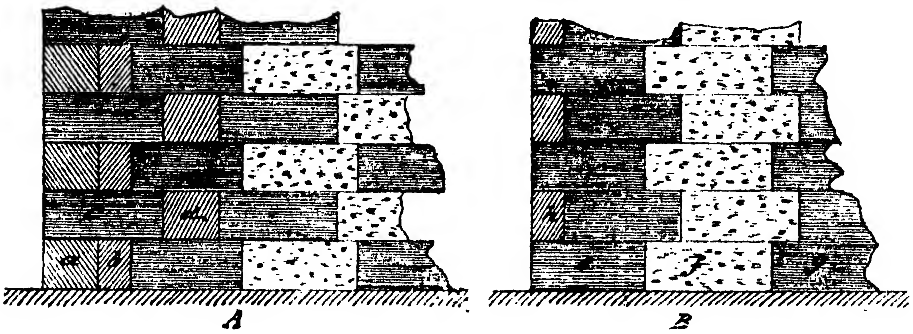


Fig. 42.

the first course in fig. 43 to be a row of headers, and the next five courses all stretchers, as *c c*, etc., we have a species of bond much used by bricklayers in the North.

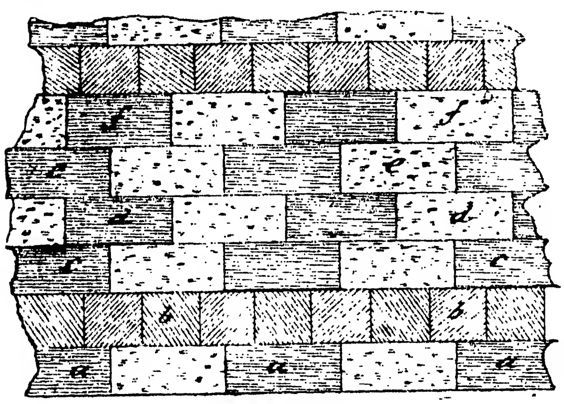


Fig. 43.

Brick Arches.

The last department of bricklaying we shall illustrate in ordinary or plain work, before taking up the subject of ornamental brickwork, is "arches." In the papers entitled "The Stone Mason" the reader will find the general subject of arches explained. In mason work the stones of the arches are cut into certain forms

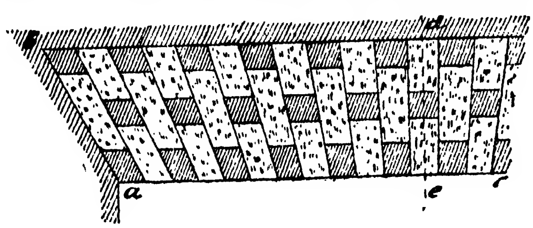


Fig. 44.

dictated by the kind or class of arch; the different stones having each a separate place to fill and a distinct office to perform, and being designated accordingly. In brickwork, as all the pieces are of the same and uniform size, they may be and are used indiscriminately, so far as the individual pieces are concerned, so that there is no distinctive name given to any one piece in the collection used by which to form the arch. It is therefore only the shape or section of the arch, and the way in which the bricks are individually set in relation to that form, which gives the distinctive character to the arch and the name by which it is distinguished from some other form. The forms of the arches and the names by which they are known are illustrated in the following figures. In fig. 44 we illustrate what is called a "flat arch," sometimes a "straight" arch, and in fig. 45 a "camber" arch. This has some of the elements of a true arch, as the lower edge or line *b c*, or what may be called the "intrados" (see "The Stone Mason"), has a slight curve; but as the centre of this curve is very distant from the intrados or curve line,

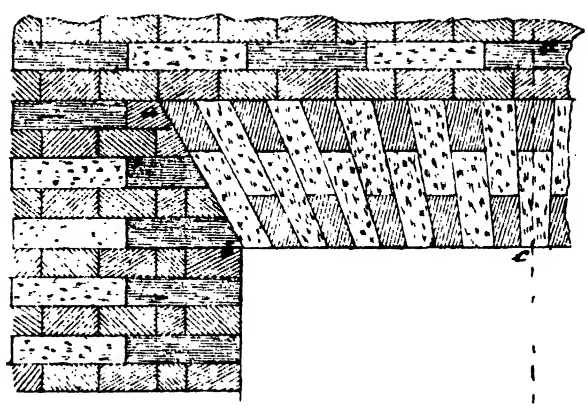


Fig. 45.

the bricks are so disposed that they all converge to a series of points nearer the line *b c* than its true centre. This in practice causes all the bricks to be of different shapes. To get those shapes the bricks are cut or rubbed down. The flat or straight arch illustrated in fig. 44 possesses none of the features of a true arch—unless, indeed, it may be in the fact that the bricks are so disposed as to make the whole act as wedges, any superincumbent pressure acting upon them tending to force them down to the side or retaining walls of the opening spanned by the flat arch.

THE COTTAGE AND THE VILLA GARDENER.

THE LEADING PRINCIPLES AND PRACTICE OF THE ART

CHAPTER III.

Cultivation of Herbs in the Cottage Garden (*continued*).

WE concluded last chapter (vol. i. p. 315) by offering some remarks on the cultivation of herbs, or "pot herbs" as they are generally called. In addition to their value in cooking, we may add another reason for this: that in many districts, where the cottage is situated near to or within reasonable distance of large towns or villages, the labourer may realise a few shillings by their sale; for their use, at least that of many of them, is rapidly increasing amongst the better classes in Scotland. In England it will be seen, from what we have said, that there is no lack of demand for this kind of garden produce. The supply in every season and district is frequently, indeed, unable to meet the demand. The cultivation of herbs is a matter of extreme simplicity; and one great advantage they possess is this,—that a plant which is worth a good deal in the season may be put down in any odd corner or piece of ground, which could not be otherwise occupied by another crop. Of course, the better the soil the greater the produce, and it will take very little time to dig and manure a plot a few inches square. As a rule, herbs are by no means particular as to the soil or aspect in which they grow. The only point to be attended to is that the plants, or plots of plants, should be kept separate from one one another. This, however, in place of being a disadvantage, is the reverse, as it obviously favours the economical plan already noticed of cultivating them in any odd corner of the garden, as corners or unoccupied spaces will be found at different parts of it. Of course a thoroughly wet soil should be avoided, except in case of mint, which is a water-side plant, and which will do with a large amount of wet or watering.

Herbs are raised either from seeds, or by slips or cuttings. Mint, for example, is cultivated by slips. There are several varieties grown, but that most in demand for mint sauce and the like is known as spear mint. The cuttings should have a small portion of root attached, as they will take more quickly to the soil; but mint, for example, is so easily grown, that it may be raised from moderate-sized slips without a root. It may be planted at any time save during frosty weather; but the best period is the early spring. It grows with great rapidity, and soon spreads over a wide surface of ground, so that a smallish plot soon becomes to the cottager worth a goodly number of pence, as a penny or twopence will in many districts be got readily for a very small bunch of it. Mint is all the better for being occasionally divided and thinned out; and in many cases a trifle will be got for cuttings, or they may be dried for use in the household. They need and should not be thrown away, as they are far from being useless. Thus a few slips mabe tied up in a bunchy and a number of bunches hung up near the fire and dried; or the drying may be done better and more quickly by spreading the cuttings loosely on a tray, placed at a moderate distance from the fire. When dried and rubbed between the hands, a coarse powder is produced, which, if placed in bottles securely corked, will keep for any length of time in a dry place, and may be used for flavouring dishes, or even for making excellent mint sauce, at times when the fresh plant is not easily obtainable. The same plan may be adopted in the case of other herbs, such as sage, sweet marjoram, savory, thyme, and indeed nearly all the varieties grown for seasoning and medicinal purposes; and for the whole of them nearly there is a great demand for the dried bunches and the powder amongst herbalists, of whom nearly every town and village has one or more. There is also a demand in hotels and large establishments, and we have little doubt amongst families also; so that we believe the industrious cottager and his family might add by this means a trifle to their income, and being industrious they will not despise any trifle, however small. We have thus pointed out one or two directions in which even so trifling a department as that of herbs may be made the means of adding to the health, comfort, and economical resources of the cottage.

Cultivation of the Ordinary Vegetables of the Kitchen Garden.

Of the ordinary vegetables, the cottager, as in the case of herbs, should aim at having as wide a variety as possible; not only because changes of food are desirable, so far as mere taste is concerned, but because the chances are, should disease attack one variety it will not attack all, so that he will have something to fall back upon, which would not be the case if he grew only one or two kinds. But to these points we have already made special reference, so we pass on to consider some special crops which could be added to cottage gardens with great advantage, where as at present the crops only grown are those one or two such as form the sole produce of many gardens, as potatoes and cabbages. An excellent root, not grown so largely as it deserves to be, is the *parsnip*. One advantage which this root possesses, independent of its value for the table, is its hardiness and adaptability to almost any kind of soil; and although, like all other vegetables which are under careful cultivation, it will abundantly repay any care given to it, still a good crop can be raised with very little labour, either in the way of manure added to the soil, or its after cultivation. It also possesses the capability of standing almost any degree of frost; so

that it can be allowed to stand out all the winter, being taken up as required. Another root making a very nice addition to the table vegetables is the *beet-root*. Care should be taken to have the seed of this true, for many beets are grown which are nearly half "mangolds," whitish in colour and earthy in flavour when cooked; whereas the true beet is a rich or crimson red, and the flavour deliciously sweet. It may be boiled and eaten as a carrot, or when boiled allowed to get cold, and cut into thin slices, over which vinegar is poured; it makes a nice relish to any dish of meat. In boiling care should be taken not to puncture it with a fork, or otherwise break the skin, as it will bleed and part with its juices to the water. *Cabbages*, we need not say, should always form one of the main crops of the garden. When the spring cabbages are ready for cutting some pull up the stalks at the same time. This is right enough if the ground is immediately dug and planted or sown for another crop, but if not it is simply waste. For if the stalks are allowed to remain in the ground, a succession, till the next season, of what may be called harvests of delicious sprouts, may be had for many months. These sprouts are as delicious as Brussels sprouts are in their way. Red cabbages should always be grown—not many, but a few, according to the size of the family. It is a mistake to suppose that they are only used for making pickles; cut up raw and with vinegar they form an excellent salad, or an addition to a salad. Unless *beans* (the broad Windsor) be disliked by the family, they should always form part of the crop of the cottage garden. Of all the table vegetables they are possibly the most nutritious. Their flavour, however, is generally spoilt or much deteriorated by allowing them to grow too long; they should be pulled when quite soft and juicy. The Germans make a delicious dish of early beans, and when they are very young they are as sweet as green peas. *Peas* are favourites with all. In sowing both beans and peas a great mistake made is putting in the seed far too thickly. It should always be remembered that plants to thrive well and yield largely require ample supplies of light and air, and in addition the soil near and around the roots should be stirred as frequently as possible, in order to allow what are called the "atmospheric influences," as air, and rain, and the warmth of the sun, to penetrate into the soil, to add as they do certain constituents, and to set others free which are present in the soil, which are all so much food to the plants. Now, these great advantages, so sadly overlooked, cannot be obtained where seed is sown too thickly; it is obvious, too, that less seed will be required, and although this may not be a great matter, still the adage should never be forgotten by the cottager, "a penny saved is a penny gained." The same attention to economy in every department should be given, so that when added together the whole saving effected will represent a sum worthy of notice.

Cultivation of Extra Crops which bring Good or "Fancy" Prices.

While the cottage gardener devotes his attention chiefly to ordinary vegetables, he may have time to give some of it to the care of one or more branches of what may be called extra work; and these, while acting in a large measure as an amusement, and in its interest a counter-attraction to the beershop, will at the same time yield him no small profit; helping to make up a little purse very acceptable in the hard times of winter. He will gain the largest profits, of course, if he can devote himself to the cultivation of one, or at the most two things, which, being luxuries, and in demand by the well-to-do, fetch what may be called "fancy prices." The bent of his inclination or taste will decide him as to what branch he will devote himself to: it may be fruit, or flowers, or something special, such as mushrooms or asparagus; or, if his garden be well sheltered and the soil good, very early potatoes or peas. For fruit there is always a demand; and of this, black, red, and white currants will perhaps yield him the largest profits, supposing he has comparatively little time on his hands. We have known a family of two grown-up people kept for a long period of the summer largely on the produce of a few rows of currant trees, some red, others black—and these not very long rows either. Of course, the most was done to make them productive, but this required no great skill, simply close attention and a little labour; the last consisting chiefly in the application of liquid manure, obtained from a very small brick tank in the garden, and the application every day of all the household liquid refuse. Black currants can scarcely have too much liquid manure; the largest and finest we ever saw of this fruit being from trees growing out of the side of a mill dam—the trees having sent their rootlets to the rich mud at the bottom.

If the cottager can "knock up" a small glass-house against the wall of his house at which the fireplace is situated, if the aspect of that be favourable, he may add considerably to his income, and greatly to his healthy amusement, by raising various crops requiring heat, a very small amount of extra artificial heat being required. Those having a natural taste for gardening soon learn to cultivate tomatoes, grapes, and the like; and in some instances so as to eclipse professed gardeners. We have heard of one man who, in a small plot attached to his house, had raised a glass structure in which he grew tomatoes, which produced him a yearly income not far below thirty pounds. This may be considered exceptional. But there is no doubt that much more can be made by attending to the cultivation of what we may call "fancy fruits and vegetables."

THE MARKET GARDENER.

His Work in Producing in Bulk, Vegetables, Fruit, and Flowers.

CHAPTER IV.

At the conclusion of last chapter (vol. ii. p. 171) we stated that on clayey under-soils the water will remain stagnant, and whatever grows there will be backward in growth; nevertheless, level, low-lying lands, if not humid, are better than arid and hilly lands, which are rarely chosen as the sites of market gardens. Before choosing a piece of land, one very essential point is to ascertain what means there are of procuring water, especially in the case of the best kind of well-drained soil, which, enabling the water, as it does, to pass through it quickly, has great need of irrigation in times of heat.

Importance of an Ample Supply of Water to the Market Garden.

Very often a plentiful source of water is the secret of success; and a stream near at hand is such an advantage that sometimes the choice of ground may well be decided by it. In default of running water, a reservoir established, if possible, in the middle of the garden, will frequently suffice. In view of the construction of such a reservoir it is necessary to see at what depth water lies underground, and this can easily be ascertained by measuring the level of the water in the nearest wells. In large gardens the water is distributed by pipes which run under the paths and terminate in several smaller reservoirs or tanks.

Market gardens should be freely exposed, and wholly uncovered—although "glass" in modified form and extent is often required—but, if possible, sheltered from the cold north and north-east winds by belts of trees or by screens of thickets.

Aspect of the Market Garden.—Division into Working Plots.

The position of a garden with respect to the sun, or its aspect, is an important consideration. A piece of land exposed to the east or to some part between the south and the east, and which has a slight downward slope in that direction, is preferable to any other, so far as regards exposure to the sun and inclination. When, however, as generally happens, one has to deal with land which has already been made into a garden, and of which therefore the position is unalterable, all that can be done is to divide it up—or lay it out, to use the customary expression—in the manner best suited to the various crops to be raised there.

Laying out a Garden.

In laying out a piece of ground, whether previously cultivated or made into a garden for the first time, square beds and straight parallel beds should have the preference. On these beds the gardener can work with most ease and expedition. The size of the squares is a matter of choice, but they should be disposed in such a way as to facilitate work as much as possible. The straight parallel beds should be 4 ft. or 4 ft. 4 in. wide, but not wider; for, if so, operations upon them, as weeding, digging and so forth, will be inconvenient to perform. A man of average height should be able to reach the middle of the straight beds without having to walk on them, and this he can do easily from either side walk if the breadth of cropped land between the walks—*i.e.* the beds—does not exceed 4 ft. or 4 ft. 4 in. The narrow paths separating these beds ought to be made below them in the form of trenches if the soil is damp and clayey, but on a level with them if it is dry and sandy.

Trenching or Deep Digging.

Land about to be made into a garden should be dug deep only when the soil is sandy and of little depth, and may advantageously be mixed with the under-bed of clay; or when it is wanted to blend a clayey soil with a sandy under-bed; or finally, when the surface of the ground has been exhausted by previous cultivation. For two years after having been dug deep (say to a depth of 3 ft.), land is unfavourable to plants; but after that period it becomes exceedingly good for vegetables of every kind, and above all for root vegetables, which, able to penetrate the soil easily, grow to a large size, and are of fine quality.

Deep Digging of the Soil.

Deep digging has also the effect of making injurious grasses spring up. For seeds lying buried deep beneath the ground retain their germinative property for years and years, and begin to develop directly they are raised up and so brought within the agency of the atmospheric influences of air and moisture, and of sunlight. The following is the way in which deep digging or trenching is generally performed. A trench is made, about 3 ft. 4 in. wide by 2 ft. 2 in. deep, and of indefinite or convenient length, and the earth from it carried to the other extremity of the piece of ground, where the digging will terminate. Then a second line of earth is dug up and thrown into the space left by the other, and so on, until finally the last trench is filled with the earth from the first.

While it renders the ground less fertile for a couple of years, deep digging is an expensive operation. Experienced gardeners, therefore, recommend that it be done, not all at once, but by degrees, from year to year, so that in the fifth or sixth year the proposed depth shall have been reached, and all the soil above it shifted. In this case the annual expense of digging is inconsiderable, and the ground, instead of being made less productive for a long while, improves immediately. (See remarks on deep culture in the paper entitled "The Farmer.") Ground which

has been dug deep at one operation needs, moreover, a great deal of manure. The vegetable bed, formed by successive decompositions of animal or vegetable organic substances, having been displaced by the spade, its place at the surface is taken by soil more or less crude and sour from beneath, and, until the latter has been under the influence of the air a long time, and well manured, vegetables will not find copious nourishment in it. Though there is no fixed time for ordinary digging, the autumn is a favourite season for it. In the autumn, ground which is not planted with winter vegetables should be dug or turned over, or, as a great many prefer, formed into ridge-like beds. Experience has shown that land which is dug before the winter is very much improved by the frosts and cold, which have such an effect upon it that at the approach of spring the clods crumble away. The same effect can be produced in summer, when the sun will gradually turn dug or turned-over soil into a good tilth. In either case the ground, having become soft and porous, is easily penetrated to a considerable depth by the atmospheric influences; and these agents aid in the decomposition of the fertilising principles which, upon becoming soluble in water, are absorbed by the roots and rootlets of the vegetables.

Sandy and clayey soils are also much improved by being dug. On any soil, in fact, fine crops are often due simply to the work of the spade. When instead of digging it in the usual way the gardener wants to form his ground into ridge-beds, he proceeds as follows. With the aid of a cord or line he marks out parallel strips of some 16 inches wide, and 4 ft. 4 in. apart, and then digs each of them with the spade to a certain depth, placing one half of the earth on the right and the other on the left. This earth he then cuts up into spits or slices four inches thick, with which he covers the surface of the 4 ft. 4 in. ridge-beds enclosed by the trenches, doing this in such a way that the slices, unbroken, lie touching one another, or partially superposed, like the tiles on a roof. The more surface the spits or spadefuls present, the better will the atmospheric influences be able to act upon them. Another style of work is performed as follows. A trench is opened, and the earth from it carried to the other end of the rectangle, where the digging will terminate. Then a second trench is made and the earth out of it thrown into the first one. and so on, until finally the last trench is filled up with the earth lying in reserve from the first. The clods should not be broken up on the surface of the ground, but when they are in the trenches. The breaking up is done by cutting them into slices not more than four inches thick, each of which is shaken to pieces on the spade, not merely turned over and deposited. This last particular is of great importance, for to a large extent it will determine the quality of the crop. The workman ought not to stand in the trenches to dig, as some do for convenience, for by this means the soil at the bottom of the trenches becomes compressed, and will hinder the growth of the vegetables. Clayey and tenacious soils are only dug in dry weather. To work them when humid would make them impermeable to the atmospheric agents, and thus for a long while barren. As to the levelling of the surface of "beds" little need be said here, since it simply consists in here filling up, there reducing, until a level surface has been obtained. Smoothness is given to this surface with the rake, previously to the seed being sown or the plants being transplanted.

Manuring.

The market gardener uses many different composts in addition to farmyard manure or dung, which is his mainstay, for manuring his different crops. Their growth is thereby increased, and the soil prevented from becoming very dry, as well as being kept porous. The following are some very good composts:—Stable litter, with a good deal of cowdung (stirred up several times in the course of the year); a mixture of leaves and muck heaped up together (and stirred as often); chalk mixed with fresh or dried plants, heaped up together and watered with an alkaline solution, or with lye-washing water (similarly stirred); blood from the slaughterhouse, mixed with chalk and soft earth; tan which has been used, blood, lime, and sand, all compounded together (heaped up and stirred as above); old decayed manure taken from broken beds, which have been used for forced culture; pigeons' or fowls' dung. Indeed, almost everything of an organic nature which can decay, and which generally we call waste or refuse, may be used to add to the value of the manure compost heap.

Straw Dressing for Soils of Market Gardens.

A system which in itself combines the advantages of a manuring to the surface, and of shelter from cold winds or early frosts to the young and recently transplanted plants, is much practised on the Continent. In this straw is spread over the surface between transplanted plants, and this also has much the same effect as manure. It keeps the ground fresh and porous, while preventing a too rapid evaporation of water; and, by gradually itself decomposing, supplies the plants with a continual nourishment, which water carries down to the roots. Moreover, it prevents an accident which all low plants, such as strawberries and lettuces, are liable to. Very heavy rain makes particles of earth spring up on to the face of the lower leaves, whose pores are thus closed. Hence an injurious partial interruption of one of the most important organic functions—namely, the absorption by the plant of humidity and atmospheric influences.

THE MACHINE MAKER OR GENERAL MACHINIST.

SPECIAL EXAMPLES OF HIS WORK—ITS LEADING TECHNICAL PRINCIPLES AND DETAILS.

CHAPTER V.

THE last paragraph of the preceding chapter (vol. i. p. 291) referred briefly to the difficulties and disappointments the early machinists had to contend with in getting work done. And "sad" enough, beyond any doubt, were the disappointments they met with. If in the case of models such as those Watt based his larger constructions upon, the difficulties were great, what must they have been when these larger constructions, the working engines themselves, were put in hand? The mere weight and the bulk of the various parts to be dealt with increased infinitely the difficulties of forming and finishing them.

The Machine Shop of the Present Day, with its Various Tools and Machine Tools, had no Existence in the Early Days of the Trade.

For, be it remembered—what the mechanical student nowadays is so apt to forget — that in the early days of the profession of mechanical engineering there was not even the shadow of an approach to what we now know as a "machine shop," with all its multiplied mechanical appliances and machine tools, by which parts, however heavy, can be handled, so to say, with ease, as well as formed and finished by the various machine tools and appliances. The machine shops of our early machinists were but little better furnished than is the smallest forge of a country blacksmith now. And so far as the fittings of such are concerned, they are better off than were our ancestors; for if they had the lathe, the best form they had of it was but rude and ineffective compared with even the worst which a country blacksmith has now; and the lathe, and the boring bit and brace, may be said to comprise the whole of the machine tools with which our early machinists were furnished. As for the "thousand-and-one" contrivances which distinguish the machine shops of the present day, they were in those early days simply conspicuous by their absence, —and however much the help they give was wanted, it is clear, from what we know, that the mere conception of machines to do the work had not even entered into the minds of our early machinists. It is but yesterday, as it were—for in the history of a people a generation or two is but as a day—that the first attempt at a "planing machine" was made by Richard Roberts; and rude enough in its construction it was, for rudeness and roughness were inevitable concomitants of a machine when the machine tools themselves were lacking by which alone roughness could be avoided.

The Difficulties of the Early Machinists arising from the Lack of Tools, present also in the Department of Materials for the Making of Machinery.

Nor was the difficulty in the matter of *materials* with which our predecessors in machine making had to contend less grave or difficult of solution. Strength and durability were obviously requisites in machines which had to deal with great resistances; and *iron*, in one or other of its forms of cast or wrought, was obviously a material better calculated to furnish these two valuable attributes than *wood* (*steel* was in those days literally one of the precious metals—as difficult practically to be had in bulk or weight as gold—so that its use was confined exclusively to tools, and those were of the smallest).

But how to make the iron, then the best material, available, was not by any means so obvious. Cast iron was certainly more readily worked up—or, more correctly to state it, moulded or cast—into the forms required; but even here the limit of practical use was far below the line reached in more modern times, and at an infinite distance, practically, from that within the compass of the work of the present day. But although iron founders of those early days did now and then produce some work wonderfully good, —as some of our older readers will remember, from the remains of old machines still existing in their youth—such as the large cylinders, for example, of atmospheric pumping steam-engines—cast-iron work generally was characterised by the rudeness and roughness of all mechanical work of the time we write of. But when iron malleable or wrought had to be dealt with by the early machinists—when the forms in which it was required were comparatively large and heavy, the difficulties attendant upon giving it those forms were so great that, almost as a general rule, practically the attempt to use them was given up, and wood, as the material most readily adaptable and the most easily worked by the tools of the period, was that which was adopted. And this the machinists were compelled to, not merely because their means of handling and working it with facility and accuracy were wanting, but because the metal in such bulk or size was not manufactured.

The Tools and Materials at the Command of the Machinist of the Present Day suggestive of Grave Considerations to the Technical Student.

In the very readiness with which materials of all kinds are now supplied to our machinists, and in mere size or dimensions as far beyond the dreams as they were beyond the reach of early machinists, the technical reader of the day is too apt to smile at such early work shown in the few specimens of it to be seen in our museums, and in such works in remote and rural districts as are still extant. But it was no smiling matter with the early machinists, and the real wonder

is that with the means at their command, and these not only limited in number but rude in construction and generally inefficient in operation, they did the good work they turned out. And another lesson may be learned from this, at which one has no reason to smile, but rather to be ashamed; and this is, that with all the appliances now at their command, with the machinist of our day it ought to be an impossible thing that bad or even comparatively good work should be turned out from any one of our machine shops. Good work always should be given. How far this is a possible thing, or rather how far it is on the contrary possible to turn out truly bad work, let such of our readers say who have wide experience of the work of our machinists generally. The writer of these lines has had opportunities, not given to many, of examining machines to a very large extent; and he is compelled to say, disagreeable as it is to do so, that machinery is often turned out yet so bad —we do not say in design, for with that at present we are not concerning ourselves, but in construction and finish—that many of the early machinists would have been ashamed to have turned it out of their modest and unassuming "forges." Whatever those early workers lacked, as lack to a woful extent we have now seen they did, of material aids and helps for their work, they assuredly did not want the high moral tone which, so to say, compelled them to do the very best, and only the best, work they could produce.

And in this connexion it is specially worthy of note here, that it is very difficult indeed to overestimate the value of their work as ministering to that progress in mechanical design and construction to which nationally we owe so much. The young technical reader may feel well assured that this progress did not rest solely upon a question of materials, but on the high *morale* of the men who in the early days gave them the shape and form which made the machines what they were, and led straight up to what in their best forms they now are. The debt the machinists of to-day owe to their predecessors of years ago is a great one, and scarcely, we fear, estimated at its value as it ought to be. Whether all of our young technical readers will believe that the facts and considerations now stated are of the highest and most suggestive value as influencing their career as the working machinists of the future, may perhaps be open to doubt. But we rest in the assurance that some at least amongst them will perceive most clearly how far and how much the lessons they teach are calculated to promote their welfare, and to enable them to take that high position in the future as workers in the wide school of mechanism which we are at least hopeful that they will assume.

It will serve a useful purpose if we follow up the remarks we have made by glancing at the practical considerations connected with the work of the early machinists, which led gradually but surely up to the forms of parts of machines, and to the improved methods of construction and mechanical arrangement now in use; and also very briefly at the investigations of scientific men, and the rules and calculations of practical value to the mechanic which they deduced from them.

We have seen how very little the machinists of early times—that is, those we have specially referred to when machinery began to be a practical power in doing work—were indebted to the theoretical disquisitions of the early writers, by no means limited in number considering all the circumstances of the times. It is indeed, as we have hinted at, very questionable whether the early machinists were even acquainted with the existence of those ponderous tomes, in which those theoretical disquisitions and an infinite variety of diagrams and "astonishing pictures of astonishing machines"—for there was no such thing as what we know as mechanical drawing or orthographic projection—were given. And even if they had had an acquaintance with them, it may well be supposed that it was by no means of a close and intimate observation. For, apart from the not very attractive nature of their contents—working men being then, as now, somewhat afraid of, or at least easily enough repelled by, long arrays of mathematical formulæ and algebraic combinations of x and y—the very extent over which these contents ranged, the mere area of paper covered by type and diagram, precluded the possibility to working men of finding and giving the time necessary to read, far less to study them. Conceive of a man who had daily work to do sitting down to the earnest study of a work such as Leupold's "Theatrum Machinarium," which appeared in the first quarter of the last century, or about 160 years ago, in the form of *nine* volumes, each volume portentously ponderous and portly. It may, therefore, be reasonably assumed that the early machinists got very little help from such works of pure theorists as then existed in the way of design for machines calculated to do the prosaic work of every-day existence.

Early Practical Machinists got Little Help from the Science of the Day.

If the early machinists got little in the way of *design* to help them in this direction from the wonderful combinations of lines which their authors and describers glibly promised would do wonderful work, but which after all was done only in imaginatiev description, they got less from the works of the authors who revelled in the marvellous as to the details of *construction*. In point of fact they got nothing.

ORNAMENTAL WORK IN MOULDINGS.

(BEING ONE OF THE SUB-SECTIONS OF "FORM AND COLOUR IN INDUSTRIAL DECORATION.")

CHAPTER II.

AT the conclusion of the last chapter (p. 175, vol. i.) we showed how a perfectly plain-surfaced beam stretched overhead across an opening would, if strong and durable, fulfil its office well enough: that is, it would be useful. But thus placed, it attracts no notice; the passer-by gives it but a glance, if he even gives that, and if looked at at all, the only mental satisfaction it gives is that it looks strong enough to bear the weight put upon it, and sound enough to bear it long without giving way. But that plain surface of wood may be so adorned by the cunning hand of the carver artist, that children stop to gaze up at it with wonder, men linger long below it to study it with delight. Fig. 2 will illustrate in a simple way how ornament can be added. Here, whatever be the opinion or criticism as to the value of the ornament as such—although both examples are from established practice—there will be no dispute as to the fact that the objects, or beams, as in this instance, in fig. 2, are more pleasing to the eye than the beam *a* in fig. 1. Although the ornamental lines in fig. 2 may not come up to the standard of some particular theory of beauty, it will be at all events conceded that they give some satisfaction to the eye—that they "look better," as the phrase is, or to use the fashionable word, they are more "æsthetic," than the plain surfaces in *a a*, fig. 1 (vol. i. p. 175). Figs. 1, 2, 3, 4, 8, 9, 10, and 13, Plate CCXIII., convey beyond all doubt the idea that "mind" of some kind or another has been bestowed on the work; but the form as illustrated at *a* in fig. 1 (p. 175, vol. i.) might have been put up by a savage who had only so much skill and such tools as to give a flat surface to his beams. Fig. 1 at *a* represents "construction," the three sketches in fig. 2 represent "construction adorned," or, as we have already seen it named by some, "ornamented construction." Figs. 2, 4, , Plate CCXIII., and figs. 1, 2, 3, 8, and 10, Plate CCXVI., are given here as further illustrating the point so far as surface decoration is concerned—those being in a kind of ascending scale, reaching what is in point of fact a high stage of ornamented construction.

Ornamented Construction further illustrated in Connection with the Sectional Forms of Beams.—The Characteristic Feature of Mouldings.

But the beam may not be so created ornamental in surface in the way indicated in preceding paragraph. It may be so placed, in projecting from the surface of the wall on which below it rests, or to which above it gives support, as to show an outline of the very plainest, on the part so projected or coming forward. The beam in this instance attracts no attention, unless it be to find fault with it that it projects at all, its plainness being thus made all the more obvious. But that outline may be so altered that grace is given to it by the lines, as in the different diagrams in fig. 2, which are supposed to be end views, or what constructionists call cross or transverse sections. And simple as the outlines are, still when in place, and put under the effects of sunlight and the shadows which this produces, looked at along its length, or without a "full-face view," it may become beautiful. All the more so when the "tooth of time" aids Nature—not the sooty smoke of crowded towns—in imparting those delicate shades and tones of colour with which, while she conceals the ravages of time, yet adorn and dignify them.

"Mouldings"—"Moulded."—Brief Glance at some of the points involved in these Technical Terms used in Building Construction.

By thus giving a changed or changing form to the

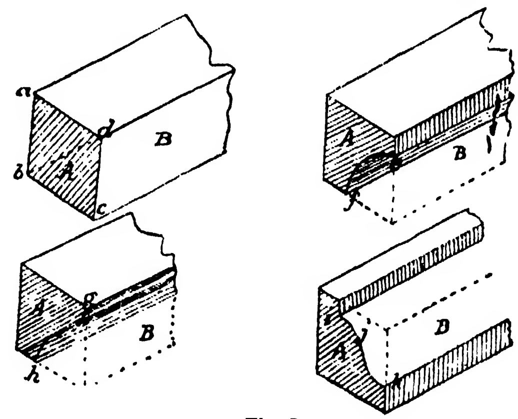


Fig. 2.

otherwise flat surface of a beam or a block, we have a series of surfaces to which the term "mouldings" is given—and when given, the objects are in technical language said to be "moulded," or "molded," as some prefer to write or spell it. That they in using the last form of the spoken word have departed from the true meaning of the word, is held by some; it is doubtful, however, whether this be so if we look, as we now shall, at the derivation of the term. The word "mould" is generally applied to the matrix in which an object is cast; the two words "mould," "matrix," being interchangeable in common language, although the first is that most generally or popularly used. The interior of the matrix or mould is made with certain lines, so as to give the definite form desired; and the material which is poured into or pressed into the interior in a molten form, as a metal, or liquid, as fluid plaster of Paris or gutta-percha, is said to be moulded, more frequently "cast." If the material be not fluid, molten or melted, but soft, such as wax or plastic clay, and is

pressed into the matrix or mould, the term "cast" is not or ought not to be used, but the term "moulded." Casting is associated with the pouring, or as the technical term is, "running in" of a molten or liquid substance,—moulding with pressing or forcing in; in both cases a matrix being used. If the word "mould" is derived from the French *mou*, which means soft, the spelling of the word "moulding" is correct,—if it be from the Icelandic *Mold*, the Latin *mollis*, "soft," or the Spanish *molde*, giving it as "molding," as used by some, is right. *Mold* in Icelandic means soft earth or soil; and the reader will perceive that this quality of softness associates itself better with the pressing of a soft plastic material into the mould or matrix, than with the running in of a molten metal or of a liquid substance afterwards capable of hardening into it. The French technical word equivalent to our "moulding" is *mouleure*.

When an object is treated through the medium of a matrix or mould, as above stated—this latter being of a fixed or indestructible character, so that it can be used repeatedly under a succession of "runnings in" or of "pressings"—it conveys the idea of a permanent character being given to the "form" which the matrix or mould impresses upon the material operated upon. This involves also the power of reproduction or repetition, so that when once a matrix is made we can get any number of "moulds" from it we choose to have, so long as the matrix remains perfect. Popularly, moulds are termed "casts," and with this term is always associated the idea of an established, or what is called stereotyped, form; this latter word, indeed, involving the idea of moulding or casting, and meaning literally a *solid* (printing) type run or cast from a liquid metal poured into a matrix (*stereos*, the Greek for solid or firm, and *tupos*, a type). Hence some maintain that the term "moulding" means simply established or generally received forms or outlines used in the decoration of the objects employed in building and the other constructive arts. The reader must decide between the conflicting claims of the two definitions.

But whether moulded by the pressure of the hand operating upon a plastic material forced into a mould, or whether made by casting or running in molten or liquid substances into moulds, the result in either case clearly carries with it ideas of a *mechanical* process. Mind, no doubt, must have been given to the formation of the lines of the matrix or mould; but once that was given and the matrix made permanent, any one of almost the lowest intellect could get a repetition of the moulding or cast object, so that a number being used in separate cases, each user might profess, if not honest, to have originally designed it; while in reality his use of it would in no way have called out his intellectual faculties to design it, further than the mere pouring into the matrix or mould of a liquid, and finally hardening or "setting" or pressing into it a plastic material. And although, for obvious and convenient reasons, we have a series of established "mouldings"—technically so called—and adhere to their use in their established or stereotyped forms, the reader will perceive how not a few of our highest authorities object to the continued use of those established or stereotyped forms, or rather we should say the constant use of them. And this on the ground that, having them ready to hand, our artistic workmen—so called—have no necessity, at least none of a pressing character, to put forth their own artistic powers in the production of form or "contour" for solid objects, thus giving their evidence of their own powers of design. There is very much of an important principle involved in the point here raised, and as it affects in reality the status of design amongst us, it will afterwards, in this paper or in one or other of the companion papers, in some fashion occupy our attention. Meanwhile, taking the "mouldings" as established, and affording, as they unquestionably do, beautiful "contours," we shall in the course of these chapters explain the peculiarities of the different classes, with their individual members, and generally give instructions how to describe them so far as our space will permit.

"Contour" a Term used in connection with Mouldings in their strictly Technical or Constructive Sense.—Some Points connected with it.

We have used the word "contour" more than once as applied to the form of a moulding or its outlines. This term is derived from the French word *tour*, a turn, and prefix *con*, with. This at once shows that the outline of a moulding is formed of a turned—that is, a curved—line or lines. Strictly speaking, this is not so, for several parts of mouldings are made with straight lines; but as these are connecting parts only, strictly subordinate to the leading parts of the moulding, formed of curved lines, the term "contour" is generally applicable to a moulding. It is the giving of those lines which constitutes the art of drawing mouldings. And as most of the contour can be shown by parts of circles, moulding curves are said to be "described." We shall see, however, that mouldings, taking the various forms which are generally used, are of two great divisions, which may be respectively considered as the high and the low classes of "moulding design." The curves of the one are, as we have said, "described" by parts of circles—those of the other are "drawn." In the one we can make use of certain appliances or implements, so that the process of producing mouldings may be thus said to be mechanical; in the other all mechanical aids are discarded, and the skill of the hand aided by the accuracy of the eye are alone trusted to.

THE TECHNICAL POINTS CONNECTED WITH THE EMPLOYMENT OF FORM AND COLOUR IN INDUSTRIAL DECORATION.

CHAPTER IV.

In concluding our last chapter (vol. i. p. 333) we stated that the only true delicacies and tints of colour were to be found in nature. And we asked the student, as the simplest and readiest experiment, to take up a stone from the highway or road. Let him take this, then, and carefully and honestly study it, and he will, we feel assured, confess that he has seen developments of colour upon its tiny surface of which he had formed, and could not without this experience have formed, even the slightest conception. Let him go further afield, or rather let him turn to his garden, and take up some favourite flower, or pluck from some no less favoured tree an apple, a pear, or a peach, and let him try to paint it, or rather to colour on his image of its contour what he sees on its actual surface. In this case also we feel assured that he will confess we have here set him out a task which he knows he never could perfectly fulfil if he coloured a lifetime. Some artists even, of no mean fame as such, have indeed lived long lives, have done much artistic work, and have died without even approaching, to their full satisfaction, what Nature shows us so lavishly and richly around us.

Important Points to be considered in connection with Colour in Natural Objects.—Variety not obtainable only when more than One Colour is present in the Object.—Variety of Shades or Tones even in One-coloured or Monotone Objects.

We have here referred only to the variety or the combination of colour which Nature displays in so many of her charming and, to a well constituted mind, ever beautiful objects. But the pupil must not suppose that she displays change, or, if you prefer it, variety of effects in objects, where there is more than one colour present. Quite the reverse of this is the fact. To prove it—and the lesson of the proof he will never forget, if he be thoughtful and wise for his years—let him take a lesson from an orange or a lemon. This is an object in which the colour is what is called a monotone—that is, there is only one colour in it. Well! no variety there? Closely study till you see it. We do not mean look at it only, for if the pupil remember what has been said in various papers, looking at a thing is by no means *seeing* it. What, then, *does* he see in the orange or the lemon? Let him, amongst other things, carefully observe the colour of the light on the front,—a strange expression to some who think of light as having no colour. Then the colour of the shadow,—a stranger expression still to those who only think of a shadow as something, and only, black. Next let him observe—for he is sure to see, if he will but only truly look for it—the gradation of colour between the light and the shadow. And having really seen it, and drunk in, so to say, its beauty and its meaning, let him take his palette and his brush and try to imitate it. After some patient trial, we shall be much surprised if he does not also in this case confess that he sees a variety of colour of which he could have formed not even the faintest conception without having given to it the study we have here recommended him. On those points in the study of colour in the school of nature, and other illustrations showing perhaps more than one way of studying, we shall have somewhat more to say presently.

Great Powers of Patient Observation necessary to the Right Study of Colour and Colouring Effects of Nature.—Study essential to the Decorative Artist.

It is only right, however, here to remind him, or rather to enforce most strongly upon him this truth,—that the study of colour is one necessitating the outlay of much patience as regards time, and the exercise of a stern determination to know what can be learnt from it as regards mental discipline. Of time—for in truth a long life may be given to the study of colour as displayed in nature, and although one honestly learned much, at the end of it he would have sadly enough to confess, that he had still to learn vastly more. "How long," asked a lady amateur, of the class to whom all things are easy, of a celebrated artist—"How long will it be before I can colour like that?" pointing the while to some work on the canvas on which the artist was engaged. "Well, madam," was the reply—"well, if you work eight hours a day, and for forty years, as I have done, you might then know something about it," emphasizing the "something" as indicative of the fact that the lady must not then expect to know all. In truth, the resources of Nature as regards colour are inexhaustible, and it may be accepted as a truth which admits of no dispute, an axiom in art, that it has been given to none, not even the brightest and best of her followers, to know all she can teach. The pupil, therefore, will perceive what he has before him, should he determine to be a truthful colourist. It is not enough that he should use colour,—any one with a brush and a pigment can do this after a fashion,—it is essential that he should use colour truthfully, at the least that he should honestly endeavour to know what truth in colour is. And this truth, it cannot be too often repeated, is only learned in the school of nature; and how hard it is to learn we have tried to show.

So much as regards the demands on the patience of the pupil. A word only can here be given as to the discipline. We have said something already as to the habit of observation, and the difference there

is between the looking at an object and the truly seeing it. "I cannot see," said a lady artist—another of the class we have above referred to—"I cannot see *that* colour," pointing to an object one of the greatest colourists of modern times was then painting. "No! madam," was the reply; "no! don't you wish you could?" What in this anecdote we wish to draw attention to, is not so much the fact that the vast majority of people have not even this *wish* to see colour as it is, with which the great painter credited his critic,—but this, that his very reply indicated that before she could see the colour she would have to learn to see it. The eye, like the mind, has in truth to be educated; mere native force and talent are worth much, but they are even at the best powerless for good work till their internal powers are trained. This culture of the eye is one demanding, then, what we have just said is essential—the exercise of stern determination to know what Nature is prepared to teach. We can do no more, however, for the present, than point out the direction of the path in which the pupil has to go. Progress in it depends on himself alone.

Patient, Observant Study of Nature essential to the Artist.

In the remarks on the important subject of the employment of colour in industrial decorative work in the preceding paragraph, we said towards its conclusion, that the lessons to be learned about it in the school of Nature are inexhaustible, simply because her examples are infinite. It is impossible to overestimate the value of lessons there to be learned, or to say too much by way of impressing the student of design to make them the chief source of his knowledge of the subject. We cannot too earnestly advise him to make its observation, as it exists everywhere around him, a matter of close concern. Let him cultivate the habit of seeing colour—much rather should we say of observing it. We have already noted the difference between seeing or merely looking at natural objects, and the observing of them; and have quoted Goethe's remark, profound in practical wisdom, that the "eye only sees what it brings the power to see." The mere looking at a thing is a purely physical act, which one intuitively does, and, indeed, if they but open their eyes in the direction of an object, they cannot help seeing it—see the object they must; but observation is an act of the mind, and it is only when they truly observe that they truly see—that is, become conscious of the existence of the object, and form their own conclusions as to what it is and how it looks. This is what is called "intelligent observation," in popular and often indeed in critical language. But in truth the phrase is somewhat tautological, and in a sense as literally incorrect as to say light is light; for inasmuch as light must be light, so observation must be and is intelligent. You may look at a thing, and you must physically see it. This you cannot help doing; and yet all the same you really do not, in the true sense of the term, see it, for you are not even aware that you have seen it, and were you asked a minute or two after you had been gazing at it if you had seen it, you would be quite prepared to assert that you had seen no such thing. And quite honestly and truthfully would you assert so, for you had no intelligent perception of the existence of the object and what were its characteristics. You had looked at it, seen it, but you had not observed; and so far as receiving any true conception of it was concerned, you might as well, for anything you had learned about it, not have looked at it at all. But the moment you look at it with your mental faculties at work on it, you not only see, but you observe, and you therefore know it. To observe, therefore, must be an intellectual as well as a physical process—observation must be intelligent and to use the phrase as if this combination were essential is as much to the purpose as to speak of a knowing *savant*. A *savant* must be knowing; he cannot be a *savant* without knowing. A man to be a *savant* in any special branch must know it.

The cultivation of this habit of observation we most earnestly press upon the pupil. No matter what be the particular branch of technical study or work, excellence will never be attained without observation. It is simply what is learned through it which constitutes the difference between the man who knows and the one who does not. And in reference to the special point of colour we are now concerned with, anything like a correct notion of what it is can only be gained by the habit of close and constant observation.

But the pupil in the art of industrial decoration must take special note of this, that because he observes an object—that is, sees it mentally as well as physically—it by no means follows that he sees or that he observes it correctly. He may, but he may not; but to help him to the "may," and convert it to his use, he has to bring to bear upon it the knowledge of others. And this, which is but the result of the experience and observation, he has to search its records for. This knowledge may be communicated to him orally by an intelligent teacher in general study. It is to be found in practical records; hence the phrase or proverb "all knowledge lies hid in books." We have endeavoured in the foregoing pages to communicate some of the knowledge which has been stored up by others—in other words, we have told him what is "known" on the subject of colour, with of course special reference only to its application to ornamental design.

While the pupil will derive some knowledge from what we have said on the subject of colour, and may

have thus given him an idea of the direction in which he should further study, let us impress upon him again—and the advice can scarcely be too often repeated in the case of beginners—that he will learn more after mastering those first principles which we have in preceding sentences told him of—infinitely more by observing the effects of colour as displayed on all sides around him—than by years of study of books. And by way of encouragement to the young pupil, or one inexperienced in colour, upon whom we impress this close observation, let us tell him that he will be well repaid for such attention as it demands. This, indeed, is but poor and cold language to use in connection with the study of colour. While this study is to be applied in practice, in the actual manipulation of pigments applied to his designs, we have written the foregoing lines to little purpose if we have not convinced him that his school for the true study of colour lies in the world around him. And if this study be gone into by the pupil with an earnest and anxious desire conscientiously to apply the lessons which Nature will teach him, to look at things with a mind free from preconceived notions or pitiful prejudices, we feel thoroughly well assured that he will thank us for urging the study upon him. At present, knowing, as we presume that he knows, but little of what colour is, and what every scene and every object in *that* scene can tell him about it, he can form no conception of what pleasure is before him. And this school for study is ever and always open to him; and but little time after he enters it all the notions which are attached to the terms school and study will have vanished, for he will find that of Nature a treasure-house of delights.

He who has the power to *observe* colour as it is displayed in the innumerable objects of nature, and above all, he who can appreciate and enter, so to say, into the very soul of what colour teaches, has a gift or power which, as has been truly observed by one who himself has the gift in great perfection, "is worth specially thanking God for."

If the pupil sits down to this study "clothed and in his right mind," he may rest assured that he will learn more lessons practically useful to him in his work, from a single hour's observation of some particular scene or object, than he could possibly learn from days' practice in the school, or from the prosy prelections of some one learned in the art of colour—of the primaries, secondaries, and tertiaries—of complementary colours, etc., and the technical language of the class.

This ability to *observe*, this capacity to *appreciate*, colour as everywhere abounding in nature, is a gift bestowed naturally upon but few. But it is a gift, happily, which can in large measure be got, and in some senses so easily, that it may be said that it can be obtained simply by the looking for it and the study of nature. To say this is but to repeat that one has but to observe and to be content to observe, when the glories of the gift will be revealed to him. We have said that it is but few who possess the natural ability to see and appreciate the colour everywhere. It may, indeed, be safely asserted that the vast majority, even of educated people, have not the slightest conception of the *endless varieties* of colour, their tints and tones, as spread out everywhere around them. They tell you of the sky, that glorious canopy, that it is clear or that it is cloudy; of the sea, that it is rough or that it is smooth; and of the fields, that they are green or that they are brown or bare. But this is all they speak of, for it is all that they observe. Not content with an ignorance which deprives them of intellectual pleasures infinitely outweighing in value all those which are so highly valued by the world of everyday life, they deny flatly that beautiful effects exist at all, in sky, sea, or field. If those to whom these beauties are revealed in all their infinite depth of loveliness and of meaning, happen to describe, or rather attempt to describe, —for of those beauties, such as they actually are, "nor tongue nor pen can tell"—what they have seen in the way of colour in nature, they are put down by nine out of ten of such people as mere enthusiasts, who fancy only that they have seen, but what *they* in their superior position know cannot exist. It must be so, they argue, for *they* have not seen such beauties; and surely if they did exist they could be seen by every one. To statements such as these—and we do not in any wise exaggerate them—what reply can be given, but that such people do not see what they so glibly deny the existence of, and that simply because they do not observe? They do not observe, first, because they do not wish to do so; and secondly, because they have not the faintest possible conception of what loveliness lies everywhere and always around them, but to them unrevealed. If they had some conception of this, we do believe that they would learn to observe, —the which if they did we can well fancy them repeating the saying of the man of old, "This I know: I was blind, but lo! now I see!"

So completely ignorant are many—we might almost safely say the great majority of people—as to what wonderful variety and loveliness of colour there is in natural sights and scenes, that, rudely as some deny the existence of this when one to whom this beauty has been made known attempts to describe it in words, they have still more pungent criticism to offer when an artist attempts to depict on paper or on canvas what he has seen in sky, sea, field or hillside, mountain scene or hoary cliff.

THE ORNAMENTAL WOOD WORKER AND DESIGNER,

In Carpentry and Joinery, chiefly for Exterior Work.

(BEING ONE OF THE SUBSECTIONS OF THE PAPER ON "FORM AND COLOUR IN INDUSTRIAL DECORATION.")

CHAPTER IV.

IN describing fig. 6, Plate XXI., at end of preceding chapter (vol. i. p. 283), we stated that the edge formed a pleasing curve from one end to the other. Or rather it may be said that it starts from a central point and

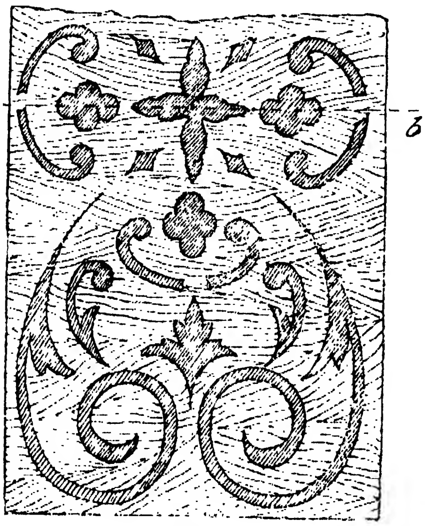


Fig. 4.

extends right and left. Further illustrations of edge treatment are given at *a a a* in fig. 1, Plate XXI., and contrasts between those and fig. 2, which any one could do, may be made with advantage. Perforated work, as for a panel in the lower part of a garden

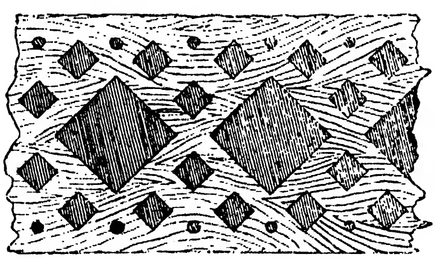


Fig. 5.

structure or summer-house, is further illustrated in fig. 9. So also is this class of work illustrated in figs. 3, 4, 6, and 11, Plate XXI.

The Foregoing Examples of Detail Ornament in Wood Work contrasted with Plain Bald Surfaces of the same Extent or Size generally.

We do not say that these drawings show perfect design; but, in many respects very good, they would form, beyond a doubt, a much more pleasing feature in a timber structure, than bare, bald, flat surfaces of boarding, or even with such parts pierced with plain meaningless apertures, when apertures are desired. But where apertures even of the simplest form, as squares and circles, are formed in boarding perforated

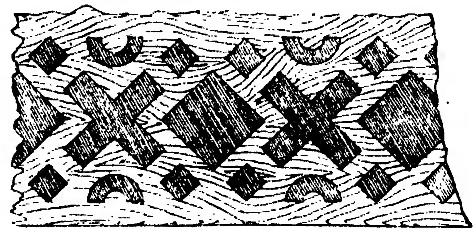


Fig. 6.

work—as for the ventilating apertures at the upper part of structure—the mere disposition of these holes, simple as they are in themselves, may give an effect, pleasing or otherwise, according as the disposition of the apertures is arranged. Thus the drawing in fig. 5 shows as simple a form of aperture as can well be found, but the disposition being harmonious gives a pleasing effect. This is further seen in fig. 6, where simple squares are alternated with curved parts, and with diagonally-placed rectangles forming crosses. The larger squares set diagonally might be filled in with a panel, also perforated, as shown in fig. 5, Plate XXI. In fig. 4 the apertures are largely circular in form, mere holes forming a chief part of the design; yet the disposition of the simply formed apertures being harmonious, a pleasing effect is obtained. What can be more simple, considered as

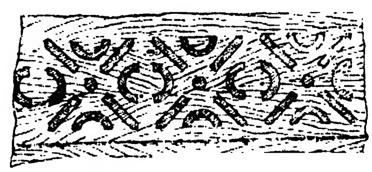


Fig. 7.

individual members, than the apertures in fig. 7?—yet how effective the disposition as a combination!

Ornamental Wood Work in Brackets.

Let us now take two classes of work in timber or wood construction, and the pupil will be able to judge whether our strictures in the preceding chapter were well founded or otherwise, and whether there be not some scope for the work of "the ornamental designer" in connection with it. Should he still require further evidence, however, on these points, we must beg of him to accompany us to the end of this section. Take the case of a bracket, *a a*, as in fig. 8, supporting what is called a "cantaliver," *b b* (see the paper under the head of "The Carpenter" for a description of this), projecting from the face of a wall, *c c*. This bracket *a a* would do its work well if strong enough, however plain its outline is; but if this were altered to the form shown in fig. 9, or that in fig. 8, Plate LXII., it will be admitted that a more pleasing effect would be

obtained; still more so in fig. 7, Plate XXI., as curved lines are more pleasing than straight ones, and a com-

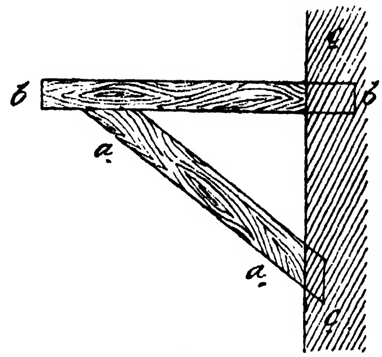


Fig. 8.

bination of straight lines with curved ones is always effective.

Ornamental Wood Work—Balcony Front.

Let us next glance at another class of work in ornamental wood construction—taking for example a balcony front. This may be made up of plain solid boarding, perhaps crowned with a simple cornice, or it may be inclosed within simple rails of wood with plain rectangular spaces between. Or it may be, still advancing in design, treated as perforated work, based on some one or other of the designs we have given, or as on those we shall have yet to give. Or it may be treated in some such a style as in fig. 3, Plate XXI., or in a still more advanced style as in fig. 11, same Plate. This last is a window-flower balcony, and is frequently a feature in Continental

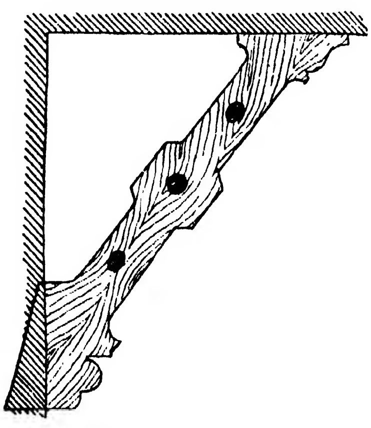


Fig. 9.

architecture, where flower culture is everywhere carried to great perfection. This design of *jardinière*, as it is called, is a specially pleasing one; we are indebted for it to the pages of the fine work edited by M. César Daly, architect of Paris, and entitled "The Domestic Architecture of the Nineteenth Century." The design itself is from a house in Strasburg by M. Schlagdenhaussen.

The Elements of Ornamental Work in Timber Designing and Setting out of Different Figures and Forms.—Ornaments based on the Triangle, the Square, and Rectangle.

Having in the two preceding chapters opened up the subject of ornamental wood-work, we now proceed to give details which may be considered as the elements or alphabet of the art. We shall begin with perforations, which, as sketches yet to come will show, play a very important part in the decoration of wood-work for various structures. The elementary forms of perforations are divisible into two classes—the combinations of right or straight lines (see "The Geometrical Draughtsman"), and of circles and parts of circles. The chief of these forms we severally illustrate in figs. 10 and 11, those in fig. 11 belonging to the circle.

In fig. 10 the simplest is that of the triangle, of

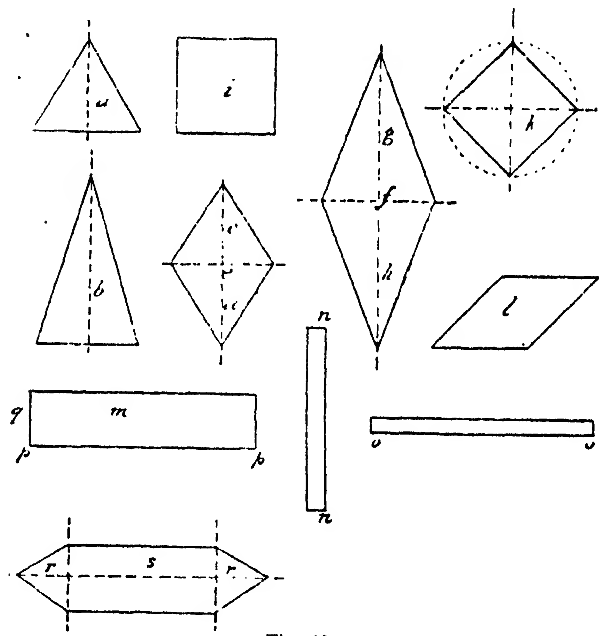


Fig. 10.

three lines, the fewest which can be employed to form a surface or an inclosed space. The two triangles available for the purposes of perforation are the equilateral, as in *a*, having the three sides of equal length, and the isosceles, as at *b*, having two of the sides equal. By joining two equilateral triangles, as *c*, *e*, *d*, at their base, another form of straight or right lined perforation is formed; and another by joining two isosceles triangles at their base, *f*, as *g* and *h*.

The "square" perforations form inclosing sides—all at right angles to each other: this set, with its base, as *i*, horizontally, forms a perforation which may be deemed ugly; but a very material improvement is effected by setting the base, as *k*, at an angle, this forming what is known as the "diagonal square"—sometimes the "lozenge," which latter name is given also to the perforations at *c e d*, *f g h*.

THE LAND DRAINER.

DRAINAGE OF LANDS OR SOILS SUITABLE FOR THE CROPS AND LIVE STOCK OF THE FARMER.—ITS HISTORY, PRINCIPLES, AND PRACTICE.

CHAPTER VII.

FROM an impression that injury to the land by wetness arose entirely from rain-water falling on the surface, in the system of draining adopted by Mr. Smith, as stated (vol. iii. p. 116), the drains were laid nearer the surface than subsequent experience has shown efficient drainage requires. To produce efficient drainage as a basis of improvement of the fertility of the soil, both underground and surface water must be dealt with, and, when in redundance, removed from the reach of the roots of plants. If the case of a somewhat flat surface of clay, or peat, even of many feet in depth, incumbent on wet sand, be taken, it will be found that the water from the sand will be continually rising towards the surface through the superincumbent soil, precisely as water ascends in a piece of loaf-sugar, or in a sponge, until the column of water so rising has attained such a height that its force of gravitation exceeds the capillary attraction of the soil in which it ascends; and however frequent shallow drains may be laid in soils under such circumstances, they will have no effect in preventing wetness in the active soil from the ascension of water from below.

A much more efficient, and more generally applicable, system of draining than had previously been practised in modern times consists in a modification of Mr. Smith's method introduced, as we have already stated, by Mr. Josiah Parkes, consulting engineer to the Royal Agricultural Society of England, some time previous to 1846. The mode of draining as introduced by Mr. Parkes is similar to Mr. Smith's system in the drains being at frequent and regular intervals; but the former-mentioned differs from the latter in the drains being of a considerably greater depth, and in their distance apart being, in some measure, under circumstances to be explained hereinafter, regulated by their depth. The depth of drains under Mr. Parkes' mode being much greater than in Mr. Smith's system, the drains by the former-mentioned method will intersect a greater number of underground water-feeders in the subsoil, and thereby prevent their outburst at, or rising towards, the surface, than by the latter, and so, in some measure, perform the function of draining springs. The mode of draining introduced by Mr. Parkes being much more effective than any other method previously in use, and it being moreover fully adequate to meet every requirement to be fulfilled by the most effective drainage, it will be the only method that will be referred to in subsequent remarks on the modern system of thorough draining by covered drains.

Position and Direction of Collecting Drains.

In determining or deciding upon these points the first thing to be done in thorough draining is to determine upon a proper outfall of the drainage water from the covered drains into an open watercourse, which should be provided, or put into a state of efficiency if already existing as a natural stream or of artificial construction, that the water may be conveyed from the main drains without impediment, or with as little obstruction as circumstances will admit of. The next matter will be to trace a main or leading drain from the outfall along the lowest level of the ground to be drained.

Although a very trifling fall will give motion to water, yet, whenever it can be avoided, no drain should have a less descent than 10 feet per mile, or 1½ inch to the statute chain of 66 feet in length. Whenever the descent of ground in which a main drain has to be carried exceeds 10 or 12 inches to a chain, it will be preferable to lay out the drain in lengths or reaches at uniform falls of less than 8 inches to a chain, and to connect such lengths by inclined planes—letting down the water from the lower end of the higher length to the higher end of the lower length—than to maintain one uniform descent with so great a fall.

When the ground is flat, and the subsoil of a uniform nature, it matters not in what direction the drains run, providing the main or leading drain be along the lowest level of the ground to be drained. On sloping ground, the direction of the collecting drains should always be in the direction of the slope, and not across it; as by the first-mentioned direction every stratum of the subsoil to the depth of the drains is certain to be intersected, by which the water in the feeders in the subsoil will be intercepted by a drain, and carried off thereby before coming to the surface; whereas by the latter-mentioned direction, the drains will be as likely to miss as to intercept the water feeders in the subsoil, and will, therefore, be uncertain in efficiency. It seldom occurs, however, that the declivities of ground are in but one direction. When the ground falls in two directions, the proper direction in which to lay the collecting drains is in that of the watershed of the surface, which is always in an oblique direction between the two declivities —nearer, of course, to the steeper. The direction referred to will be more readily comprehended by a reference to the accompanying diagram (fig. 6).

In setting off small or collecting drains on ground having two declivities of surface, let the direction of the declivities be, in the first place, determined; and then, by levelling, ascertain the gradient of each. The gradient is the quotient of the distance levelled being divided by the difference of level in the distance. Then measure, from the same point *c* in the main

drain, in the direction of each declivity, *c b*, *c d*, up their rises, distancing *c f* and *c e* proportional to their gradients. Next measure the distance *f e* as the third side of a triangle *c e f*, which third side must then be divided in the proportion which the other two sides bear to each other. The proportional division of the third side spoken of will be by the following proportion, viz.:—As the sum of the two sides in proportion to which the third side is to be divided is to the third side, so is either of the other two sides to the segment of the third side, in proportion to the side used as the third term in the proportion. The point of division, *g*, of the third side will be the distance of the smaller part from the end of the side representing the proportion of the steeper gradient, or it will be the distance of the greater part

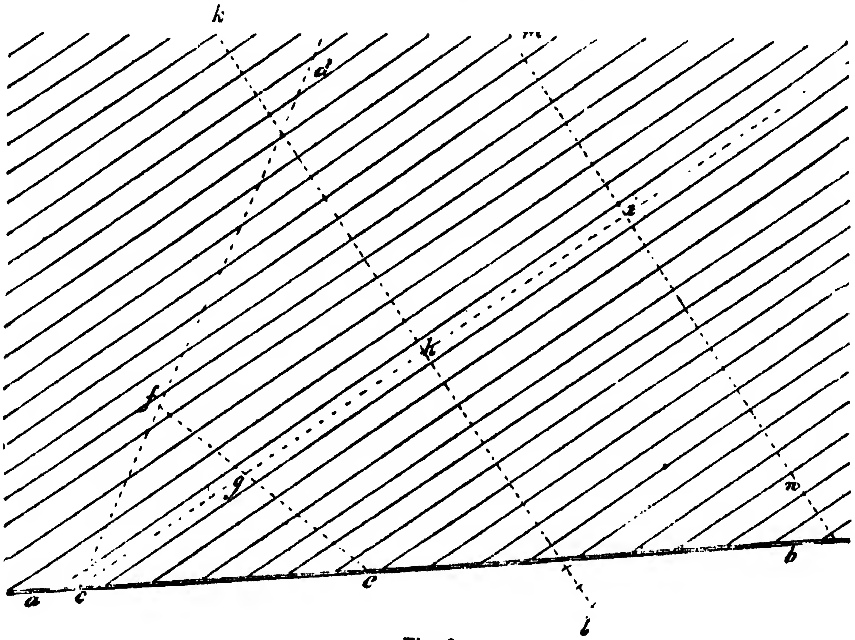


Fig. 6.

from the end of the side representing the proportion of the less steep gradient of the declivities. The direction from the point in the main drain from which the two first lines were measured to the point of division of the third line will be the proper direction of the small or collecting drains. Having, by the process described, found the proper direction of the small drains, let lines *h k*, *h l*, and *i m*, *i n*, be traced right and left to such direction, at right angles thereto, and measure on the lines so traced the distances the drains are intended to be apart, and the corresponding distances on the lines at right angles to the line of direction of the drains will be two points in the direction of each drain by which the same may be laid off in parallel straight lines to any length from the main drain that may be required.

Where several undulations of surface occur, a separate system of the direction of the collecting drains must be applied to every alteration in the plane of the surface, so that the direction of the drains in each may be that inculcated above. To those in the habit of laying out draining works the process above described will seldom be necessary to be strictly carried out, as experienced drainers can with sufficient accuracy determine the proper direction of drains by the eye; nor, unless the alteration of the plane of the surface be very marked, need a separate system of direction of parallel drains be always strictly attended to.

Collecting drains are very usually made in the furrows or valleys, between the high ridges formed by ploughing when draining was not so common an operation as it now is. Drains being so placed is no doubt under an impression of a saving being effected in the depth of cutting. The practice in question is, however, not to be recommended, for the reasons about to be adduced. In the first place, land is seldom, if ever, ploughed in the direction in which the drains should properly be carried. Water is more apt to stand directly upon the top of a drain than on any place between any two drains; therefore drains should never be in a hollow place towards which water will trend. To understand the reason of water being more apt to stand directly over a drain than in any other place, it will be necessary to glance at the nature and formation of subsoils, and the manner in which water passes from the soil to drains, which will in the next place be considered.

THE CABINET MAKER.

THE TECHNICAL DETAILS, AND THE PRINCIPLES AFFECTING THE DESIGN OF HIS WORK.

CHAPTER II.

WE concluded last chapter (vol. i. p. 116) by quoting an eminent authority on the lack of taste for decorative art amongst the general public—a statement most pregnant with meaning. But that quotation was not there completed, for the same authority goes on to explain how this miserable state of matters has come about. He points out that for long—and, indeed, it is only within the last quarter of a century that a change has taken place for the better—commerce "so called," as our authority puts it, actually insisted upon divorcing art from all branches of manufacture, "forbidding the exercise of art as an essential part of manufactured wares." And although, as we have seen, matters are mending a little, it is but such a very little that there is scarcely one branch of our manufactures—if there be indeed one—but what produces both ugly and beautiful; while the greater part of production belongs assuredly to the first rather than to the second category. But the worst part of the case remains—for, as our authority says, the ugly things are bought by the public as readily as the beautiful. And the still greater misfortune is that this is likely to be so for some time, inasmuch as, under the present system at all events, it is so much cheaper to go on manufacturing ugly things established in the market than to go to such additional expense as to produce new things which will be beautiful, or at least possess some claim to this distinction. The summary of the matter may be put in the words of our authority: "At present the divorce of commercial manufacture from art has made the public bad marketers; too often they don't know what they are buying."

Remedy for this Lack of Taste for the Decorative Arts on the Part of the General Public.

How, then, is this state of matters—pitiable enough, from an artistic point of view, it must be confessed by all thoughtful people to be—to be remedied. We have already said, in connection with another part of the same subject, that improvement rests with the people themselves. There is nothing like looking facts as they exist around us plainly and fully in the face. This is the only way to arrive at a practical result. It is folly to do otherwise: to pretend or try to convince ourselves that what we would prefer, or what we merely suppose, without any ground to base a reasonable supposition on, constitute facts. This is what no sensible man in any calling or walk of life does; he deals with facts as they are, not as he might wish or suppose them to be. And we shall witness an improvement in the development of public artistic taste so soon—but not sooner—as the public themselves begin to see that art really closely concerns their social and moral position, and seeing this, determine that art education shall be general, not confined, as it is now, to a special class supposed popularly to be the class alone interested in it. We have said that a general art education is no small matter, to be passed lightly over, and those who wish for better things can at present only wait, with such patience as they can infuse into their souls, for the coming of the better times.

Rules, Canons, or General Principles of Design—introductory to the Consideration of Design as applied specially to the Work of the Cabinet Maker.

In what is called the art of design there are certain rules or canons, or what in science would be designated as laws. Concerning these there is an almost universal consensus of opinion that they are deserving of the name, inasmuch as they cannot well be disputed. At all events, it may be said of them that by far the great majority of those interested and engaged in one or other of the applications of what for lack of a better term is called design, accept them as correct, and as points about which no dispute is to be allowed. There are many features, however, connected with the art of design which take the form of mere opinions. These are held by different men, according to the views which they individually hold as to what in certain features and under certain circumstances good design should be; and with many as frequently those views are often just as much the result of prejudice as of careful thought and observation. It need scarcely be said, therefore, that there is ground for dispute—and of this there has been enough, and more than enough—as to the value or otherwise of opinions or views so created and upheld. To some of these we shall draw the attention of the pupil-reader, especially where they have been put forward with special persistency, and have by this means gained a currency more or less wide. And in so drawing attention to them we shall endeavour to point out in what respect they are valuable, and therefore to be adopted by the young designer, or in what respects they convey what appear to be erroneous views, and which, therefore, should be avoided by him in his practice.

Meaning of the Term Design in Relation to Decorative Art.

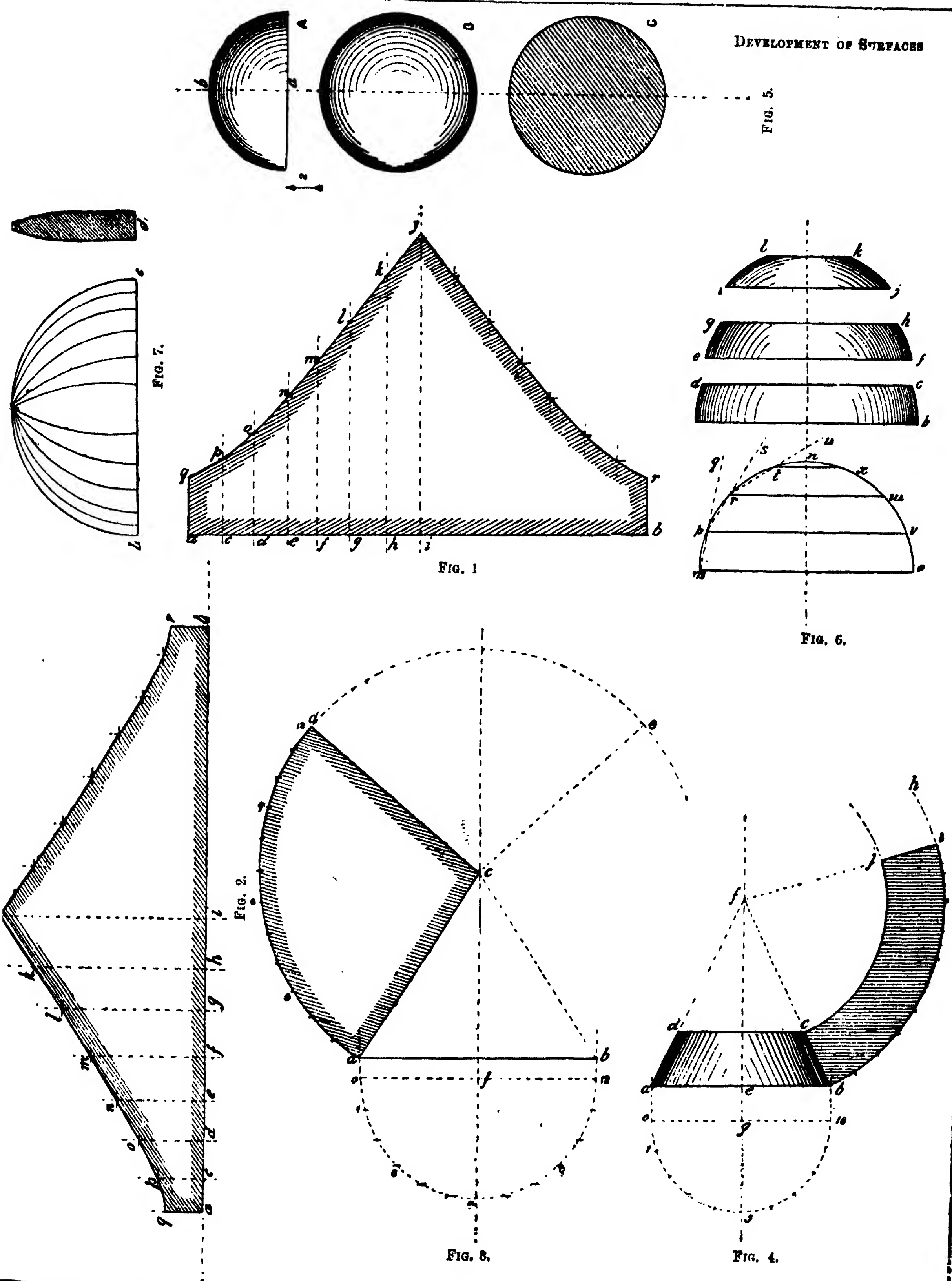
We have said that for lack of a better word the term "design" has been applied to convey an idea of what is meant when we wish to attach to any object another characteristic than that which is derived from or belongs to its mere utility. And this added characteristic is given purposely, in order that the eye may be pleased on looking at the object,

and what is called "taste" gratified in the possession of it. When this added characteristic is present in an object otherwise merely useful—that is, which serves the purpose for which it is made, be it a jug or jar to hold a liquid, or a table upon which that jug is placed—we then say that the object is beautiful as well as useful. The term "beautiful," as we shall see, is purely relative, and it is a term which is more abused and misunderstood than even that of "design," with which we are now concerned. We discard, then, for the present at least, the term "beautiful," round which clusters so much that is mere matter of opinion, and has therefore never been concreted into anything like canons or rules about which men are agreed; and we prefer to say that when the characteristic we have above named is added to an object, it is more pleasing to the eye than if it did not possess that added characteristic. About the fact that it is more pleasing to be looked upon there is no dispute. It may be, for example, that if the straight outlines of any merely useful object are so treated that they have a certain form given them by curves or by curved surfaces in relief, these curves and surfaces may be objects of dispute between those who view the object so treated. One may say that the curves used are not those which should have been used, or the curved surfaces are false in conception. Another may hold an opinion respecting them quite the opposite of this. But both or all admit that the object, with its new or added treatment, whatever that may be, is assuredly more gratifying to the eye—that is, it is more pleasant to look upon, than when in its original form with its straight lines.

In the accepted phrase of the day, an object so treated is said to have "design" applied to it; or that it has been well or badly—as the opinion of the critic may be—designed. The term "design" is so far unfortunate that it tends to vagueness and often to grave misconception; and it assuredly lacks the definite precision which should, if possible, be the characteristic feature of all the definitions of terms of art and science. The true and original meaning of the term is conveyed in the idea that we propose to do a thing. In other words, design involves a purpose or object in view. If we have, for example, an object to construct, and if we construct it so well that it answers all the purposes we had in view, and these are secured by the least expenditure of material and of labour in working it up into the finished object, we then say, as it is said by an approving public, that it is well "designed." The term may indeed, and generally is, applied also to any scheme which is purely mental—as the plan of a book is said with perfect truth to be well designed. In all work there is a purpose to serve, and to effect this is the very motive of the work connected with it. Reverting to the subject of a construction, we have seen that it is said to be well designed when certain conditions have been observed. But this construction may make no pretensions to giving form which is pleasant to look upon; may have not a single characteristic to which the term "beautiful" can in any sense be applied. It may, indeed, on all sides be pronounced unmitigatedly ugly, yet from its original and true purpose it is worthy of being pronounced as well designed. But if any one claimed for it that it was a "good design," a very different train of ideas would be brought up in connection with the object; and a war of words would assuredly ensue if to its mere utility something had been added which was supposed to give the characteristic of beauty to it. But if not, the term "design" would not be permitted to be applied to it all, for it would be said that it had no "design" about it. And yet, beyond all doubt, the object was well "designed," for it fulfilled all the essential conditions of the "purpose" the "designer" had in view.

Confusion of Ideas arising from the Generally Accepted or Popular Meaning of the Term "Design."

This confusion of ideas, this uncertainty, as to the meaning of the term design arises wholly from the lack of precise definition in the term design, as it is now almost universally used. It has got by some curious process or turn of circumstances to be associated wholly with something done in the way of adding to objects of all kinds that characteristic we have referred to, by which they are said to be more or less beautiful, certainly more pleasing or gratifying to the eye, than if not so treated. But if in the true sense of the term "design," "purpose" is involved—and no one will deny the accuracy of this—if that purpose be fulfilled, a work of any kind is just as well entitled to be called a "design" as the work of an artist, to which the term is almost universally alone applied. If there be any meaning in the word "design" at all, the conclusion is inevitable that there must be several varieties of design, as there must be numerous classes of designers. A school in which nothing but the principles of scientific construction are taught has as much right to be called a "school of design" as a school in which drawing and its application to various branches of industry are alone taught, and to which the term "school of design" is equally well, and indeed now universally applied. Yet one would never dream that in the first instance it involved the teaching of construction; while every one would know, as indeed every one knows who knows anything at all, that by the term "school of design" nothing, in ordinary language, more nor less and *nothing else* is meant than that it is a place where *drawing* and its industrial applications are taught. "This and nothing more."


DEVELOPMENT OF SURFACES
FIG. 5.
FIG. 7.
FIG. 1
FIG. 6.
FIG. 2.
FIG. 3.
FIG. 4.

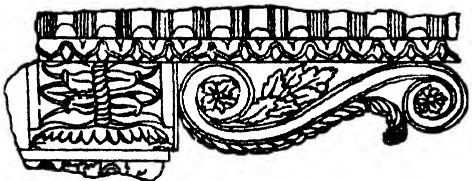


Fig. 1.

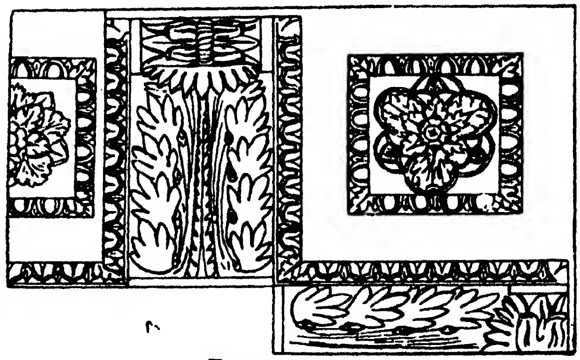
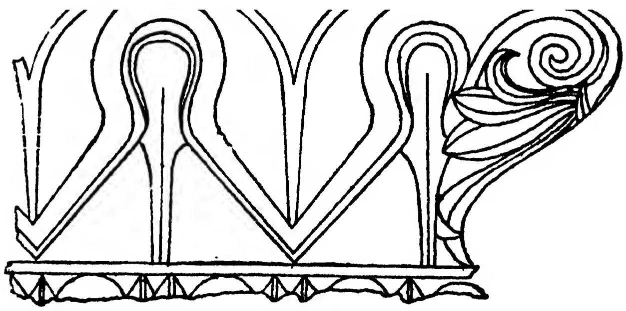


Fig. 2.

Fig. 3.



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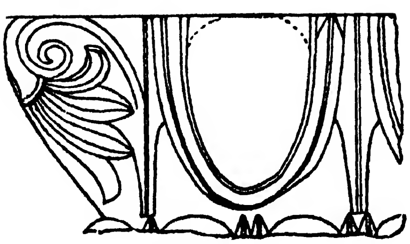

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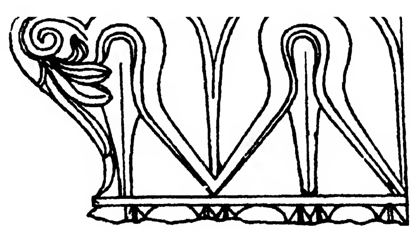


Fig. 6.

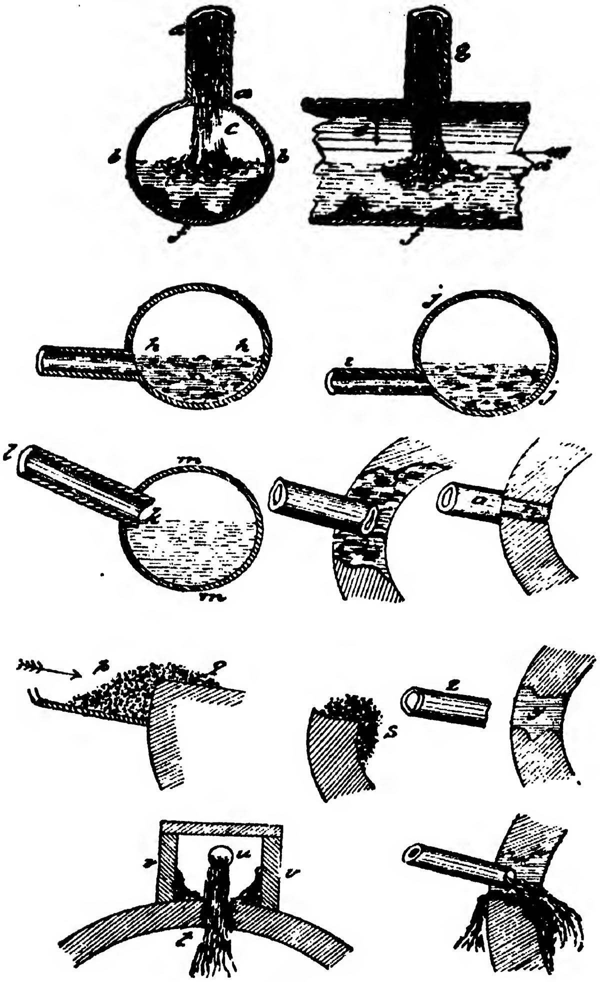


FIG. 1.

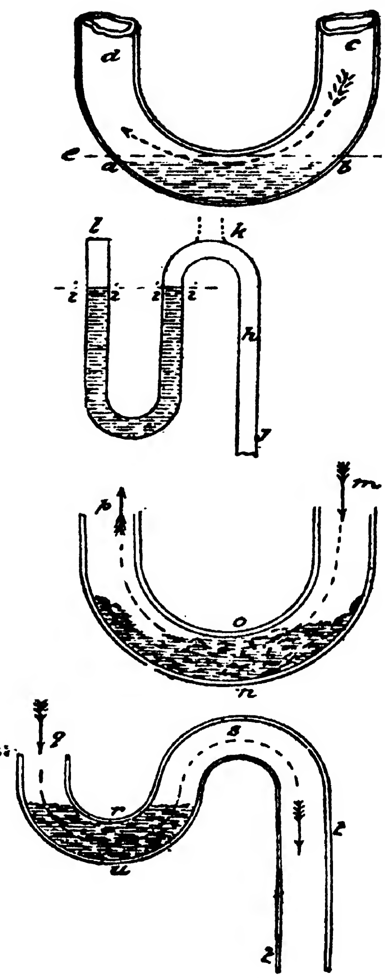


FIG. 2

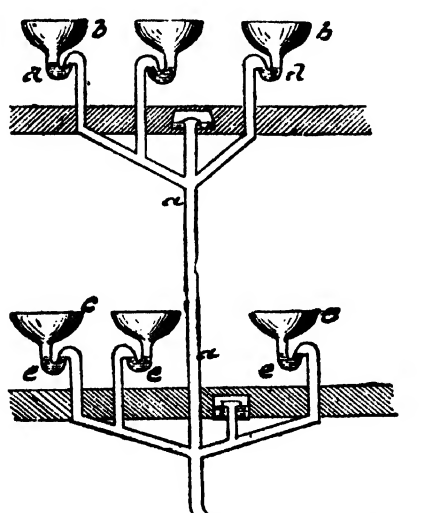


FIG. 3.

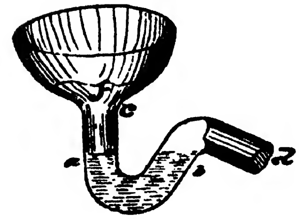


FIG. 4.

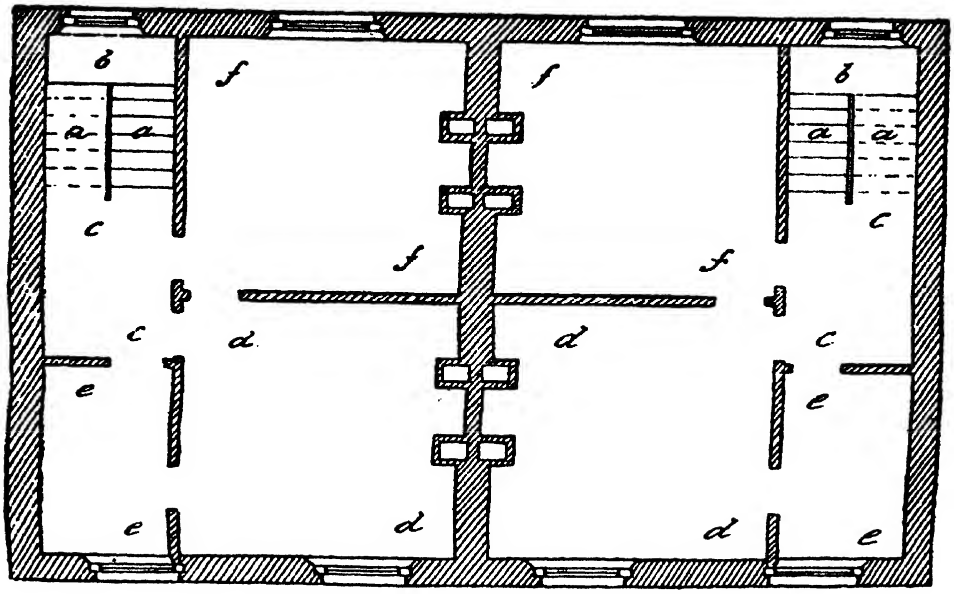


FIG. 1.

PLAN OF FIRST BEDROOM FLOOR—"ONE-PAIR PLAN" OF HOUSE IN FIG. 2, PLATE IV
See also PLATE V.

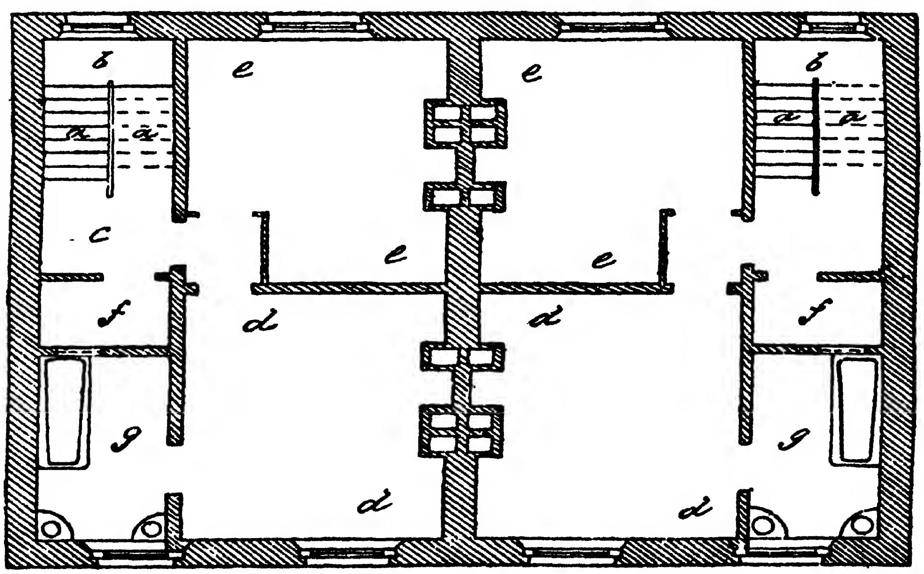


FIG. 2.

PLAN OF SECOND BEDROOM FLOOR—TWO-PAIR PLAN.

THE TECHNICAL STUDENT'S INTRODUCTION TO THE GENERAL PRINCIPLES OF MECHANICS.

LAWS AFFECTING NATURAL PHENOMENA—MATTER AND MOTION.

CHAPTER XXX.

Circular Motions—General Considerations (*continued*).

THE contrivance of the handle or winch, as exemplified in the simplest of all rotating circularly formed bodies, the grindstone—or, to give it its correct mechanical name, the crank — takes part in every combination of mechanism in which naturally straight or right-lined is converted into bent, curved-lined or circular motion: constitutes, in fact, one of the great inventions of man by the aid of which mechanical work is alone possible. And it is somewhat saddening, as assuredly, if considered in a right spirit, it is humbling to the pride of man, to think that not even the remotest trace exists to lead us up to the country where, the time when, far less to the man by whom it was invented or discovered. Like that equally wonder-working, yet of all contrivances the simplest possible in its material form, the potter's wheel, by which centrifugal force is made under the cunning direction of man to do such wonderful things in giving form and shape to plastic clay, the history of the crank is shrouded in the most absolute mystery. The name "crank" is supposed to be derived from the German *krink*, or the Swedish *kring*, a circle or roundabout; that of "winch" from the Anglo-Saxon "wince," a reel upon which yarn was wound.

Centripetal Force.

Surrounded as the student is by an infinite variety of machines in which power of one kind or another, of which steam is the principal source, is employed to give varieties of movements or of motion, the most striking, and indeed the most general of which is circular, he is apt to overlook the lessons which the simplest of all machines, the grindstone, can teach him as to circular motion. We have said that in all circular motion two forces are continually at work or in existence—the centrifugal and centripetal—and these practically are antagonistic to each other, but are, as we have seen, and shall yet, as we proceed, more fully see, in very virtue of this antagonism, of the highest practical service to man. The centripetal or centre-seeking force is that which gives the circular motion to a body, or compels it, so to say, to go in a curved direction, or be bent out of the straight line which we have seen is naturally the line of motion of a body acted upon by a force. This centre-seeking, and, as when the body is put in motion it may be called, the centre-found force, is exerted by different forces and in several ways, the principal of which will be duly described in the appropriate paragraphs hereafter. The simplest of all methods of making a body to move in a curved line or circular direction is by the direct agency of the hands acting upon its *outer* surface. This is exemplified in the simplest of all work of the kind—namely, moving a barrel or cask along the ground by pressing the hands on its surface, and forcibly extending the arms, or, as in the case of an empty barrel, trundling it along by the aid of a stick. Analysing this very simple process, the reader will see how the circular motion—which is purely a rotatory or revolving one, although to most minds it is the rectilineal motion along the ground that is the striking feature of the work—is derived from the exercise of *centripetal* force.

The term is derived from two Latin words, *centrum*, a centre, and the verb *petere*, to approach, to go near to, to seek; and to the reader interested in the meaning of terms it is curious to know that the word petition is derived from the same Latin verb; and if he thinks this out he will see its application to the mechanical term now under consideration. We

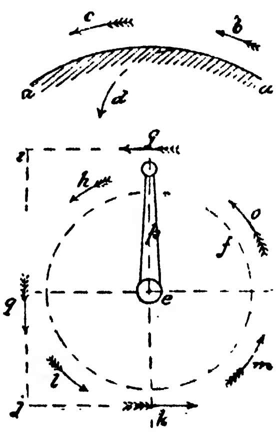


Fig. 38.

have just given a very familiar illustration of centripetal force in the rolling of a barrel or cask along the ground, and one nearly as familiar in the turning of a grindstone. The motion and the centripetal force generated may be graphically shown, as in fig. 38. We assume the curved line *a a* to be part of the surface of a cylinder or roller which receives a motion of revolution, or to use the popular phrase, turning itself—derived from the French *tourner*, to turn round, to give a circular form or motion to. The arrow *b* represents the force of the body communicated by the arms and hands to the surface *a a*, in place of this force proceeding, when continued in the direction of the arrow *a*, the solidity of the body itself keeps the hands in contact with its surface and the force moves or tends inwards, so to say as in the direction of the arrow *d*, and is communicated to the centre of inertia or centre of gravity *e* (see the paragraphs on the "centre of gravity"); and from what has been else-

where said, if we move the centre of inertia of any body, we move the whole of the body,—just as the converse is true, that if we bring the centre of inertia to rest in a body which has had motion we bring the body itself to rest. And to put the matter very familiarly, but which to the young student in mechanics will be easily understood, we can only reach, so to say, or influence the centre of inertia or the molecule or atom in which that centre may be supposed to exist through the medium of other molecules which are connected with it and with each other by the attraction of cohesion (see a succeeding paragraph for this term), and which terminates at what we call the outside of the solid body. This is also graphically illustrated in fig. 38. We reach or influence the centre of inertia or of gravity, *e*, of the grindstone *f f*, through the medium of the solid molecules of iron cohering together assuming the form

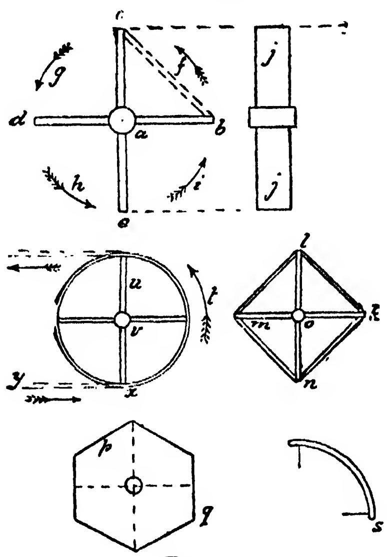


Fig. 39.

of the lever of the handle, crank or winch *p*. When this handle is pushed forward by the force of the hand, which is naturally in the direction of a straight line (see a preceding paragraph), as in that of the the arrow *g*, as it passes the vertical line *e g*, the force applied to the end of lever *c* would have a tendency to pull it somewhat in the direction of the arrow *f*, or push it in the direction of the straight line indicated by the arrow *g*; but this action of the original force, tending thus to separate the upper point *a* of the handle *a* from its connection with the central axis or axle *a*, is prevented by the cohesion of its molecules, which gives rigidity and strength to the handle *p*. On passing the vertical line *e p g*, the force applied tends inwards, being, so to say, dragged in towards the centre or through the medium of the handle *p*, and the force thus tends to the centre *c*, as in the direction of the arrow *h*. On the hand of the grindstone driver or turner and the end of the handle *p* arriving at the point *q*, the natural tendency of the force is to produce motion in a straight line, as in the direction of the arrow *q*, or line *i j*. But the same conditions exist at this point as between *g* and *i*, and the force is compelled, so to say, to "seek" or "move toward" the centre, or as in the direction of the arrow *i*. The same is repeated when the handle is brought round to the points *k* and *n*, where the natural tendency of the motion to go in straight lines, as indicated by the arrows, is changed into the curved directions at *m* and *o*, seeking the centre *e*.

The grindstone may be put in circular motion by other means than by the simple and well-known cranked lever. Let us suppose *a*, in diagram fig. 39, to be the centre of the axis or axle of the grindstone, which is embraced by a part having four levers, as *b*, *c*, *d*, *e*, all of equal length. We can further suppose that the moving force, as that represented by *d* in fig. 38, is applied in succession: first to *b*, carrying this round from *b*, fig. 39, in the direction of the arrow *f*; it is next applied at the end of arm *c*, carrying it round to point *d*, in the direction of the arrow *g*, and so on; when the last application of the force, at the point *e*, will bring it round in the direction of the arrow *i* to the point *b*, at which the force was first applied. The point *b* is thus said in technical language to "revolve" round the centre *a*; and the whole of its circular path, represented by the arrows *f*, *g*, *h* and *i*, is called a "revolution." The term "revolved" is derived from two Latin words, *re*, again or back, and *volvere*, to roll or turn round; and revolution is derived directly from the Latin *revolutio*, meaning a complete or finished turn, starting from one point and rolling round till the original point is "come back to" again. We suppose the levers *b*, *c*, *d*, *e*, in fig. 39, to be much broader than thick; the thickness being represented at *b c d e*, the breadth at *j j*, in vertical section as on the line *c e*. If we joined the terminating or exterior points of any two of the arms, as *b* and *c*, say by a solid bar represented by the dotted lines, *f*, it is obvious that any force applied to a point, as *k*, would be communicated or transferred to the point *l*, and this again through the intervention of another solid bar could be transferred to the point *m*; and the whole would be, so to say, balanced by completing the parts as between points *m* and *n*, and *n* and *k*. And if all the points were connected with a centre point *o*, common to them all, we should thus arrive at the part known as a square "reel," a contrivance used much in certain departments of textile manufactures. If there were six points we should have a "hexagonal reel," as at *p q*. In place of connecting the points by straight bars, as at *k l*, we might connect them with a curved part, as between points

r and *s*; and if this were done at all the points, as between *b*, *c*, *d*, and *e*, we should arrive at the mechanical contrivance known as the "pulley," at *t u*. This would be made to revolve or turn on its axis by the hands pressing on its surface in the same way as we would move a barrel along the ground, and with the result and in the way we have already described. In practice the moving force is applied to or communicated to the pulley by means of a "belt" or "rope," the principle of which is illustrated in fig. 39, at *t u v w x y*. Suppose a cord were attached to the point *t* of the surface of pulley, and this were led over in the direction of the point *u*, and then forward horizontally in the direction of the point *w*. If the force were then applied to the rope or cord at *w*, the pulley being free to move on its centre *v*, the point *t* would be dragged up in the direction of the straight arrow; but for the reasons already stated, it would seek the centre *v*, and therefore pass from point *t* to *u* in the direction of the curved arrow. Here the pulley would stop, as the force acting only in the direction of the arrow *w* could only tend to drag the point *u* horizontally also. But in place of stopping short at point *t*, we can suppose the cord to be continued round the under side of pulley to the point *x*, and then continued forward as shown; the part of the cord between points *t* and *x* would pull up the point *x* to *t*, while *t* would be pulling forward by the force at *w* to the point *u*. The pulling force at *w* being supposed to be continuous, the revolution of the pulley *t w x* round its centre *v* would also be continuous. When studying the practical points connected with circular motion and its contrivances, the young reader will see how the motion of the rope or belt in the direction of the arrow *w* is kept up continuously; meanwhile we have seen how centripetal force is availed of and comes into play in our mechanical contrivances.

Motion Produced by more than One Force.

We have hitherto considered motion as produced by one force only, and that acting in one direction. If there be more forces than one, but all act in the same line of direction, the extent or effect of those forces in producing motion will be equal to the sum of these forces. If they act in opposite directions the two forces will tend to destroy each other, and if equal in amount will neutralise each other, so that the body will remain at rest, no motion being produced; and if unequal, the stronger force will influence the weaker, and not only destroy the force of this, but impart what may be called the surplus of its forces to it, so that the weaker will be compelled to go back, as it were, and follow the direction of the stronger force. Thus, we can suppose a steamer capable of going along under steam at the rate of ten miles an hour, but to be under the influence of a current which we may suppose to run also at the same rate of ten miles. If the direction of the current exerting a force equivalent to a motion of ten miles an hour be the same as the direction in which the vessel is working under steam the force of which is equivalent to an equal rate, the speed of the vessel would be twenty miles an hour. If the vessel were steaming against

Fig. 40.

the current she would make no headway at all, but would simply remain stationary, the forces being equal; but if she ceased steaming she would be carried back by the current at the rate of ten miles an hour. Two balls, one of which, as *a*, fig. 40, was driven in the direction of the arrow *b*, with a certain force calculated to carry it to the point *c*, meeting another ball *c*, driven by a force *d*, equal to force *b*, would meet at

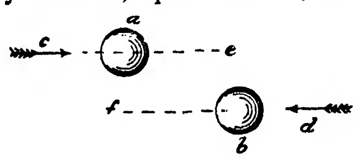


Fig. 41.

a point *e*, central to both, and would stop there, motion being, so to say, destroyed, the two equal forces, *b* and *d*, having neutralised each other. We have seen that motion is always in straight lines; the balls *a* and *b*, fig. 41, acted upon by forces *c* and *d*, will proceed in the straight lines *e* and *f*, coincident with the lines of forces *c* and *d*. The forces we have named act either in the same direction as those just alluded

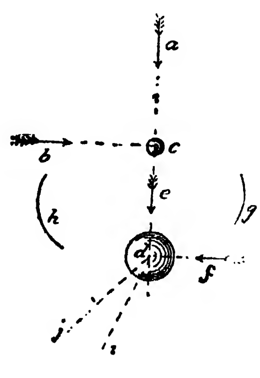


Fig. 42.

to, or in opposite directions, as at *b* and *d*, fig. 40, and may be either single forces, or each the sum of several forces. But a body may be placed under the influence of two forces, one of which acts in the direction of the arrow *a*, fig. 42, and the other in that of the arrow *b*. In this case we have two forces acting in directions quite different from each other—so much so that they diverge from a point *c*, which is

common to both, at right angles. We shall see presently that the angle may be other than a right angle, and how the difference of the angle made by the two lines *a* and *b* influence the direction of motion. The young reader, in thinking over the condition of a ball, as *d* in same figure, acted upon by a force represented by the arrow *e*, and by another force represented by the arrow *f*, but in another direction might, and at first probably would, suppose that the ball, under the influence of the two forces, would, to use the popular phrase, be bent round, as it were, somehow in a direction between the two directions of forces *e* and *f*, thus going in a curve more or less pronounced, as at *g* or *h*. But we have seen that motion is always, and naturally, taken in a straight line; the direction of the new line of motion will therefore be in a straight line, oblique, or at an angle to the lines *e* and *f*. This course, somewhere between the two lines of forces, which is the result of the action of these on the same body, as *d*, depends for its direction on the obliquity of the angle, as *e d j*, *e d i*, or *j d f*, *j d e*, upon the relation which the two forces represented by the arrows *e* and *f* have to each other. The various points connected with the action of bodies under the influence of two forces, which come under what is called the composition and the resolution of forces, will be found described and illustrated in the appropriate paragraphs in the early chapters of the "Boat and Ship Builder," to which the reader is hereby referred. Those points are of great importance to the mechanic, as being concerned in many of his operations, and should be carefully studied by him. In the paper to which reference is here made, the reader will find descriptions of the movement of ships under the influence of the wind, and of the varying position of these to the requirements of the navigator in moving his vessel in certain directions, and the description also of that curious mechanical contrivance known as the helm, all of which come under the head of the composition and resolution of forces.

Movements in Circular obtained from the Motion of Fluids in Straight Directions.

The reader will see how fluids, as air or water, impinging upon or flowing against flat surfaces placed in opposition, either directly or indirectly—that is, at right angles or obliquely—tend to press or "shove," to use the popular term, the body before it, or to turn it aside according to its position. By changing the condition of the body exposed to the impinging pressure of a fluid, we can change the motion of that body, which under normal circumstances would be in a straight line, into a motion of revolution; and hence, from the power or pressure of wind or water, which is always exerted or always acts in straight lines, obtain circular motion, which gives us a wide range of motive-power mechanism. A simple illustration of this position now named is given in fig. 43. Let *a b* represent a board acted upon by a fluid, as a body of water in the direction of arrow *c*: if loose or free to move, and if the pressure or velocity of *c* were great enough, the body *a b* would be pressed forward in the direction of the dotted horizontal lines, or of arrow *d*. But if in place of being free to move bodily away in the direction of arrow *d*, *a b* were swung or suspended from the end, as to a fixed centre *a*, the

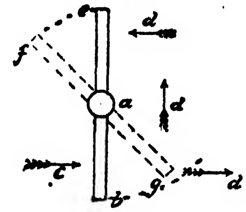


Fig. 43.

pressure of the fluid on the side *c* wo[illegible] the tendency to move the board *a b*; [illegible] is fixed at the point *a*, yet so that while fixed it permits the board to swing to and fro or turn upon the point, as an axle; the end *b* only of the board *a b* is moved, and being tied, so to say, to the centre *a*, it moves round in a circle, as shown by the dotted curve *b g*. If we suppose that in place of the board *a b* terminating at *a*, it is continued on the other side of *a*, as at *e*, as the end *b* rises towards *d* in the curve *b g*, the end *e* descends in the opposite direction, as at *e f*. As *b* rises towards *d*, *a b* assumes the oblique position as at *a g*, at which the obliquity is such that the water acts no longer upon it as a lifting power, and it therefore remains as in position *g*, and as *a e* balances, or is supposed to balance, *a b*, *a e* assumes the position *a f*, corresponding to *a g*. Here we have got a circular motion through a certain length of path measured by the distances *b g*, *e f*. But if we suppose that to the central pivot or shaft other boards are fixed similar to *a b*, radiating from the same centre, and so that as the fluid ceases to act upon one board, as at *a g*, another comes into position on the side *c*, as at *h*, we by increasing the number of boards or arms, as *a b*, shall bring up to the action of fluid *c* a succession of surfaces on which lifting or turning pressure is exerted, all in virtue of centripetal force, acting upon the centre *a*; and if we suppose this to be a shaft we have in its motion the rectilineal motion of the fluid in direction of arrow *c* changed into a continuous circular one, and which can be availed of in one or other of the great variety of mechanical movements met with in the working of machines in the doing of industrial work. The arrangement here illustrated in fig. 43 the student will recognise as that of the form of water-wheel known as the "undershot."

THE BRICKLAYER OR BRICKSETTER.

THE PRINCIPLES AND PRACTICAL DETAILS OF HIS WORK.

CHAPTER XV.

THE bevel line, as *a b* (fig. 45, *ante*), which gives this wedge-like arrangement to the arch, is called the "skew-back," being at an obtuse angle to the line *a c*. This so-called brick arch is anything but strong, as may be seen exemplified in the many brick houses in which it has given way. It is only used when cheap work is desired or necessitated. But, defective as it is, it is infinitely superior to another form of "flat" or straight arch known as the "French" arch,—which is altogether a misnomer, as it contains no element whatever of a true arch, and is altogether so vicious and irretrievably bad from a constructive point of view, that it should never be seen in brickwork which has any pretensions whatever to be considered good because honest work. Its use is altogether calculated to mislead, as it gives the proprietor the idea of security or strength which the mere name of an arch conveys, while it possesses none of it. We illustrate (fig. 46) this imported

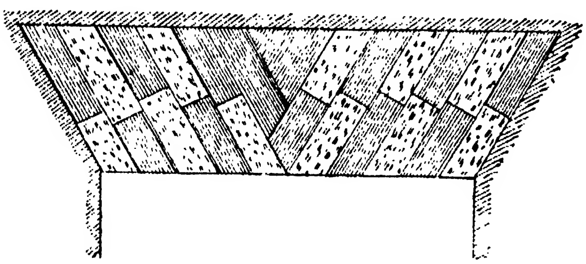


Fig. 46.

monstrosity in construction—if, indeed, its birthplace was, as is assumed, France—by way of warning off from its employment. In fig. 47 we give the disposition of the bricks in two flat arches of one brick deep, the diagram in A showing the depth as made up of stretchers, the diagram in B the arch with depth made up of two courses of headers.

The "true arches" in brickwork are the "semicircular arch," the simplest and the strongest arch of all, illustrated in fig. 1, Plate CLXXXIX.; the "segmental arch" in fig. 3, same plate; the "elliptical arch," or rather the semi-elliptical, in fig. 4, and the "Gothic" in fig. 2, Plate CLXXXIX. Of the segmental, the elliptical, and the Gothic, there are many forms.

When the bricks in a segmental arch, as in fig. 3, Plate CLXXXIX., converge to the centre of the arc, as the bricks *a a* to the point *b*, the arch is then technically called a "scheme" arch. The brickwork used in arches is termed either "gauged," "cut," or "rough" work, according as the bricks are treated; this treatment having reference to giving them the form more or less nearly approaching that which they assume when the arches are properly set out. Some of the methods of setting out brick arches will be presently given.

What is called a "relieving arch" is a segmental or scheme arch turned over an opening, as that of a door (fig. 6, Plate CLXXXIX.), *a a* being the arch, *b b* the wood or timber lintel spanning the door or window space, side or jamb of which is at *c*. "Inverted" arches are shown in fig. 5, Plate CLXXXIX. For the kind of arch known as a "trimmer arch"—being that turned over between the trimmer joists of a floor near the fireplace, and on which the hearthstone rests — see illustrations and descriptions in the papers entitled "The Stone Mason" and "The Carpenter."

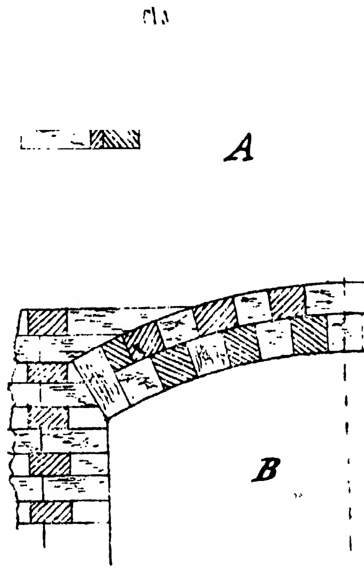


Fig. 47.

The following diagrams illustrate the methods of striking the lines giving outlines of the bricks used in the foundation of flat, scheme, and elliptical arches. In fig. 1, Plate CXXIX., we show half of a flat arch of two bricks length in depth from *c* to *d*, this depth being made up of two layers or courses—as first the course *d g h e*, and second *g c f h*, the two being divided by the line *g h*. Each course is made up of a series of "stretchers," as *i i*, *l l*, and two "headers," as *j k*, *m n*, placed alternately. To find the dividing lines, as in the direction *d c*, *i m n*, draw any line, *c f*, representing the "soffit," inner and lower surface, or intrados of the arch, and make *c f* equal to half of the span or width of opening, as a door space or a window void. From *c* to *d* set off the distance equal to two bricks length, or 18 in., and from *d* draw *d e* parallel to *c f*. From point *f* draw, at right angles to *c f*, the line *f o*. Make *o e* equal to 9 in.

or the length of a brick. In practice, however, this distance is generally $7\frac{1}{2}$ in. or thereabouts. Through point *c*, the centre of the span or arch opening, draw a line, *a b*, of indefinite length. From point *e* draw through *f* a line, as *c h f p*, which, continued beyond *p* far enough, will cut the centre line, *a d c*, continued in a point which we call *b*. This point, to save unnecessary length in the diagram, is not actually given in it; but we suppose all the problems we give to be drawn actually on the board by the student in the art of bricklaying. From the point *b* as a centre, with the radius *b e*, describe an arc *e a q*. On this arc the divisions or starting points of the bricks in the arch are set off. Take the distanec of *a r* or *r s*, equal to half the thickness of a brick, and set it off from the point *a* to *r* and *s*. From *r* and *s* draw lines converging to the point *b* on centre line *a c b*. These will give the full thickness of the bricks *i'* and *m' n'*, exactly in the centre of the arch. In all brick arches the bricks are set off so that the centre line of arch will pass through the centre of the central bricks, which thus take the place of the keystone of a stone-built arch. With the distance *r s*, or the thickness of a brick, set off on the arc *a e* an equal number of parts to *e*, as *t u v*, *w x q*. From these points draw lines converging to the point *b* on the centre line *a c b*, as *v z*. When completed the lines will be given as in the half of the arch *d c f e*; the other half, to the left of line *a c b*, being put in in a similar way.

It will be observed that, although the bricks, as *i' i*, *l l*, and *m' n'*, *m n* (fig. 1, Plate CXXIX.), are so disposed that they break joint, the joints are horizontal—that is, parallel to the top and bottom lines of the arch, as *d e*, *c f*. But to obtain the full strength of joints, they should lie at right angles to the lines or faces of the bricks. Thus in fig. 2, Plate CXXIX., let *a b*, *c d*, be the lines of two adjacent bricks of an arch, as in fig. 1, Plate CXXIX. The joint *e f* is horizontal, forming an obtuse angle with the line *c d*. The line *g h* gives the proper direction of the joint, it being at right angles to the line *c d* or *b a*, which represent the faces of the bricks. This method of setting out the breaking joints of a flat or scheme arch is shown in fig. 4, Plate CXXIX. Set out the arch, as *a b*, *c d*, so as to get the width of span *b c*, depth of arch *a b*, and the "skew back" *c d*, as explained in connection with fig. 1, same Plate. From point *c* produce *c d* indefinitely, as to *e*; from point *d f* indefinitely at right angles to *d c*, and make *d f* equal to the thickness of a brick, as *r s* in fig. 1, Plate CXXIX. From point *f* draw to point corresponding to point *b* in centre line *a d c*, fig. 1, Plate CXXIX., the line *f g*, cutting upper line of arch *a d* in the point *h*. From point *h* draw indefinitely a line, as *h i*, at right angles to the line *h g*. Make *h i* equal to *d f*, or the thickness of a brick, and from *i* draw to centre point on line *a b* the line *i j*. From where *i j* cuts *a d*, as *k*, draw a line *k l* at right angles to *i j*; and make *k l*, as before, equal to *d f*, and draw to centre point, as *a b*, the line *l m*. Proceed this way, and a series of lines, as *d f*, *h i*, *k l*, will be produced, to which lines are drawn parallel, giving the points in the arch as *n*, *o*, *p*, *q*, *r*. The lines, as *f d*, *k l*, can be made parallel to their corresponding lines, as *f c*, *l m*, by means of the set-square; but failing this, the geometrical way is shown in fig. 4, Plate CXXIX. Thus, set off on the line *c d e*, produced any convenient distance, as *d e*, from *d* to *e* and *s*; and from *e* and *s* as centres, with radius equal to *s e*, describe arcs cutting in points *t* and *u*. Through *t* and *u* draw a line cutting *c e* in *d*; *t d w* is at right angles to *d c*. The same may be done in the points, as *h*, found, and the lines, as *h g*, being drawn.

To draw the lines of the joints of an "elliptical arch," as in fig. 3, Plate CXXIX.—The curve here shown is not a true ellipse, but merely such an approximation to the true curve as is used very frequently in practice, as being more easily produced. The three centres from which the curve here given is drawn are at *a*, *b*, and *c*. The easiest, and one very commonly used to get the lines of the arch bricks, is here shown—namely, by dividing the intrados of the arch, as *d e*, into the desired number of equal parts corresponding to the thickness of a brick, as *d f*, *f g*, *g h*, etc. From these points lines, as *f l*, *g m*, *k n*, *o p*, are drawn converging to the two centres, as *a* and *b*. The lines at the points between *d* and *i* are drawn to the centre *a*; those between *i* and *e* to the centre *b*. The right-hand side of the drawing gives a clearer view of how the lines are divided,—the first set, between *s* and *r*, stopping at the line *r*, which produced goes to the centre *c*; the second set converging to the lower centre *b*.

Brick Arches (*continued*).

This method, however easy it is in practice, does not give a pleasing look to the lines of the arch, as they bear no direct relation to the curve at its different points. This is more noticeable in arches of which the curve is a true elliptical one. The diagram in fig. 5, Plate CXXIX., gives a method of finding the lines of the arch in direct relation to that part of the curve at which the line is drawn. Let *a b* be part of the intrados of the arch, and *c* and *d* the two foci of the curve. Let *e f* and *g* be the divisions in the intrados *a b*, marking off the thicknesses of the bricks. From any point, as *g*, draw lines to the two foci, as *g c*, *g d*, and extend them indefinitely beyond the extrados or outer curve of arch. Then, from point *g* as centre, with any convenient radius, describe an arc joining or cutting the lines *g c*, *g d*, in the points *h*, *i*.

THE CARPENTER AND HIS TECHNICAL WORK.

ITS ORIGIN AND EARLY PROGRESS—THE PRINCIPLES AND DETAILS OF ITS PRACTICE.

CHAPTER XVI.

Framing.—Strengthening of Beams by Trussing (*continued*).

In the preceding chapter we described at end of p. 71 the method of flitching a beam, as illustrated in fig. 1, Plate XCVI.; and in continuation of the description of this there given we come to point out that in place of the iron plate lying or pressing on the surfaces of the two beams, as at *s t*, the plate may be let into one of the beams, as at *o* and *r*; or a part equal to half the thickness of the plate may be cut out of each beam face, as at *y* in the lower diagram, in which *w w x* are the two beams in part plan. In either of these arrangements the two faces of the beams can be brought up close to each other; and another advantage will be obtained—that the ends of the plates would butt up against solid timber, and thus act in some measure as a compressive strain.

In trussing beams on the methods now to be illustrated, iron in its two forms of "cast" and "wrought" (see the paper entitled "The Iron Maker") is used in combination with the timber beams, the cast iron to resist "compressile," the wrought iron to resist "tensile" strains. How they are used to perform these offices we now proceed to show; taking first the trussed beams in which cast iron is used.

Fig. 8, Plate CLIII., gives in diagram one arrangement for trussing. The upper diagram represents the method in which the two beams to be placed together—one of which is shown at *a b*, *c d*,—are trussed by cast-iron bars, one of which, *e*, is vertical in the centre of the length of the beam, and two, *f* and *g*, inclined at an angle to this; the inner and upper ends butting against the upper end of vertical bar *e*, the other and outer or lower ends butting against bolts passed through the beam. These bars are placed between the two beams, and take the place of the wrought-iron plate used in "flitching" or "sandwiching" a beam as illustrated in fig. 7, Plate CLIII., and in fig. 1, Plate XCVI. In the middle diagram in fig. 8, Plate CLIII., the arrangement is shown of another method of trussing beams with cast-iron bars. In this the off beam, *h h h*, is shown in side elevation, two inclined bars of cast iron, *j k*, butt against bolts in pairs at their feet or lower and outer extremities, and at their heads or upper ends against the ends of a horizontal bar, *i i*, also of cast iron. In both cases two thin beams or thick planks are used, in order by trussing to make one strong beam; and placed in juxtaposition, as in the method of "flitching" illustrated in fig. 7, Plate CLIII., and as at *l l*, *m m*, fig. 8, same Plate, have the assemblage of cast-iron bars placed between them, as shown, *n n* being top edge of the bar *i i* in central diagram, *o o* the top edges of bars *k*, *k*, in same figure. In this case the bars are held in position, and they and the two beams thoroughly secured, by screwed bolts passing through the beams at convenient positions at their ends and centres, these bolts being brought hard up by the nuts with which they are provided.

The method of trussing just described, as well as that of flitching in fig. 7, Plate CLIII., has this great advantage in the case of a thick beam,—that it may be sawn longitudinally into two, and thinner beams, and the sides which originally formed the central part of the beam, turned outwards in the trussed beam. This exposes what was the centre or heart of the original beam, and allowing it to be exposed to the air it gets thoroughly seasoned, and the decay prevented which often sets in in the heart of thick beams which are difficult to season throughout the bulk. In fig. 9, Plate CLIII., we illustrate part of the centre and part of the end of a beam trussed with iron bars, either cast or wrought, although cast iron is better constituted to resist compression than wrought iron. In this the central bar, as *e* in fig. 8, Plate CLIII., is dispensed with, and the bars, as *f g*, simply butt against each other at their upper ends, as at *e e*, the ends being cut off in a vertical line. The lower ends, as *b c d*, in place of butting against a bolt passing through the beam *a*—this bolt forming one of those which secure the two beams together—is let into the face of the beam at *y* in fig. 1, Plate CI. so that the thickness of the part cut out gives a butting place for the end of *a b c d*. The bar *b c d f e* is of course let into the beam along its whole length, and so that it is either flush with the surface of the beam or sinks so deep that its surface may be a little below the surface of the beam into which it is sunk.

In the case of large beams which are trussed, a more complete method of adjusting the iron trussing bars is adopted. The details of one or two methods are shown in figs. 2 and 3, Plate XCVI.; the general arrangement being as in the upper diagram *a b c d* in fig. 8, Plate CLIII. In the method illustrated in fig. 2, Plate XCVI., the upper ends of the inclined bars, as *h*, *i*, corresponding to *f g* in upper diagram in fig. 8, Plate CLIII., butt against a cast-iron head *e e* at their ends, *f*, *g*. This head *e e* is made thick enough to admit of a bolt-hole to be formed in it, through which is passed a bolt *d d*, which passes down to the under side of the beam, and is provided with the usual form of projecting head which presses against the bottom edges of the two beams, where the bolt is screwed hard up by the nut *c c*. To prevent the nut from sinking into the upper edges of the beam, as *a a*, and to give it a good bearing surface, it is in good practice usual to give a pressing plate of wrought iron, as shown at *b b*, through which the bolt *d d* passes,

and against which the nut is jammed or screwed up. This pressing plate *b b* is shown as let into the top edges of the beam so as to be flush with their surfaces. The plan of arrangement in upper diagram in fig. 2, Plate XCVI., is shown in the lower diagram; in which *a′ a′* is one of the beams, *k k* the other placed in juxtaposition, *b′ b′* the pressing plate corresponding to *b b*, resting on top edges of the beams or let into their surfaces, against which the nut *c′ c′* is jammed or screwed up, *d′* showing end of bolt. In some cases the butting head is not placed between the beams and hidden between them when placed in the position as at *e e g f* in fig. 2, Plate XCVI., but is in place of being made of cast, formed of wrought iron, as at *e e*, fig. 3, same Plate. The lower end of this is forged so as to narrow at the point *p*, and is from that point continued downwards to form a bolt *i*, which is provided with the usual head, which is large enough to take a good hold or grip of the under edges of the beams. The head *e e* is itself of course flat, so as to give flat edges, as shown at *e′* in edge or side elevation to the right of *e e*, and the bolt *i* or "tail" may be flat also, or it may be rounded, as bolts usually are. The upper part of the head *e e* is extended upwards, as at *h*, and this part is of course rounded, as it has to form the screw bolt by which the head is jammed down or held in position by a nut, as at *c c* in fig. 2, Plate XCVI. The head *e e*, fig. 3, Plate XCVI., may be firmly secured to and held in position between the two beams—each half in a trussed beam being generally termed a "flitch"—by having a bolt-hole as shown in the centre near *g*; through this a bolt is passed, and passes also through both beams, and is screwed up in the usual way. The lower ends of the bars—technically termed "struts" or "braces," generally "struts"—correspond to the bars *f*, *g*, in the upper diagram in fig. 2, Plate XCVI., and are disposed as shown in fig. 3, same Plate. They press against butting pieces, *j*, *k*, the upper parts being extended upwards in the form of a flat bar or bolt provided with the usual "head" made broad enough to take a good grip of the upper edges of the two flitches or beams. The butting pieces, as *j*, *k*, are in the other or lower direction extended downwards in the form of a round bolt, *m m*, which is screwed to receive a nut which is jammed or screwed up against pressing plates, as *b*, *b*, fig. 2, Plate XCVI., resting or let into the surfaces of the lower edges of flitches or beams. The arrangement here described may, however, be reversed, the upper part of butting piece *j k* being extended at *j* so as to be finished at end as a screwed bolt, the nut and pressing plates being at the upper edges of the beams, while the lower parts, as *m m*, are kept flat and provided with heads, as usual. In some cases the heads or upper butting pieces, as *e e* in fig. 2, Plate XCVI., in place of being concealed between the beams or flitches *a a*, being below the upper edges or surfaces, are wholly above and rest upon them. In this arrangement, shown in diagram in fig. 3, Plate CI., at *a a*, *b b*, *c d*, in which *a b* is the head butting-piece, *d* the bar corresponding to *h g* (fig. 2), and *c* the bolt-hole, part of the ends of bars being seen above the beams or flitches. The lower butting-pieces, as *j k*, are always concealed within the beams. These may be let or sunk into the beams, as at *c* in fig. 9, Plate CLIII., in order to have a butting or resisting point; but this is provided usually by bolts, as at *o* (fig. 3, Plate XCVI.), against which they press, those bolts passing of course through both beams, and being jammed or screwed up with screw-bolt and nut. Or the lower butting-piece, *j k*, may be itself bolted to the two beams, the bolt passing through a bolt-hole as at *n*, thus affording the necessary resisting point.

Those of our readers acquainted with "roof" trusses (see a succeeding chapter on Roofs) will perceive that the two methods of trussing beams illustrated in the diagrams in fig. 8, Plate CLIII., are arranged on the principle of the "king post" (*a b c d e f f g*) and "queen post" (*h h i i j k*) principles of trussing. The same methods are adopted in trussing beams with wrought iron; but as this method is best suited to resist "tensile" or pulling strains, the ordinary arrangement of the "king post" and "queen post" trusses are reversed. Thus, in fig. 6, Plate XCVI., the upper diagram is the "king post" truss, but with the angles of the parts *c d* in the opposite direction to *f g*, corresponding parts in fig. 8, Plate CLIII. And in the lower diagram, *h h* in fig. 6, Plate XCVI., the "queen post" principle of trussing is shown, but with the parts *h i*, corresponding to *j k* in fig. 8, Plate CLIII., reversed. And this, as just stated, is done in order to meet the different conditions in which the material of the trusses, is placed. Thus the parts *f g*, *j k*, in fig. 8, Plate CLIII., are struts or braces calculated to and so placed as to resist compressile strains or a crushing force; the parts *c d* and *h i*, fig. 6, Plate XCVI., to resist tensile strains, or a pulling force.

In fig. 5, Plate XCVI., we give to larger scale the elevation of central part, and in fig. 10, Plate CLIII., the plan of under or lower side of flitches or thin beams trussed on the arrangement shown in upper part of diagram in fig. 6, Plate XCVI. In fig. 5, same Plate, *a b* is one of the flitches, *c d* the wrought-iron tension rod; this passes round the part *e*, the lower edge of which is rounded to admit of the bent part of *c d* pressing equally against it; the part *e* forms the lower termination of the bolt *f*, which is screwed to and jammed up by the nut *h* and pressing plate *g* against the upper edges of the beams or flitches. The part *e* is wide or broad enough to have a good pressing

surface against the lower edges of the beam, as shown in the plan of fig. 5, Plate XCVI., in fig. 10, Plate CLIII. Fuller details of the arrangement at central part of the truss, and of the method of securing the upper or outer ends of the tension rods *c d*, will be found illustrated in fig. 4, Plate XCVI.

In fig 83 we give in larger scale the central part of the queen-post arrangement of trussed beam in *i i j*, fig. 6, Plate XCVI. In this there are two bolts and heads, as *b b c*, placed at same distance apart, between which the tension rod is horizontal, as at *d*, and on passing round the heads *c c* are screwed up at an angle to the upper curves of ends of beam, as shown in fig. 6, Plate XCVI., at *h i*, and secured in the manner illustrated in fig. 4, same Plate. Fig. 84 (in text) is plan of upper side of the truss in fig. 11, Plate XII.; fig. 85 (in text) being plan of top side, showing the pressing plates *f f* for tightening up the truss. And it should be noted here by the reader that this tightening or screwing up of all trussed beams, in which iron is combined with timber, is done to such an extent that the truss as a whole has an upward bend or curvature, so that it is reversed as at *i j i* in fig. 82, p. 70. This provision is known, as we have explained in connection with this figure, as the "camber" of a beam, and the amount is such, as there stated, that when the beam is placed in position and supporting or carrying its load or weight, the deflection caused by the pressure brings down the beam to the level or straight line, as at *c* in fig. 82 (in text).

In fig. 4, Plate XCVI., we give the details of the parts of beams trussed with wrought-iron tension rods, as in preceding figures above described. The diagram *a a f l g* shows in section the central part of a beam, as at *b* in fig. 5, Plate XCVI., in which *g* is the tension rod passing round the head *h* of bolt *d*, secured up by the nut *c* resting on the pressing plate, as shown. The lower diagrams show two methods of securing the upper and outer ends of the tension rods *f* and *g*. In the first to the left hand, *p p* is the beam, *q* the tension rod or "tie." To adjust the nut, as the end *s* of the beam is at right angles to its length, or squared off, and as in all cases the pressure or strain brought on the tension rod *q* must be in the direction of its length, if the same nut as *t* in the pressing plate against which it rests were placed against the square end *r* of the beam *p p*, the strain on the rod *q* would obviously be out of the line of its length. The face of the pressing plate *s*, against which the nut *t* is jammed or screwed up, must therefore be at right angles to the line of direction of the tension rod *q*. This is effected by giving the form to the pressing plate *s*, as shown, which, flat on the one or inner side against which the end of the beam *p p* presses, and angular or oblique on the other or outer side, enables the strain put on *q* by the nut *t* to be in the proper direction, face of *s* being at right angles to *q*. Where the pressing plate is flat, as at *w* in the lower diagram to the right-hand side, the end of the beam *v* must be cut obliquely, so that its face is at right angles to the line of direction of tension rod *y*. In some cases no pressing or jamming-up plate is used, the nut pressing only upon the face of end of beam; in which case the end of beam must be cut obliquely, as shown at *v w*. But the practice is not to be recommended: a pressing plate should always be used, and that of as large a surface as possible. For it is a maxim in all good and sound mechanical construction that all pressures should be distributed over as wide a surface as possible.

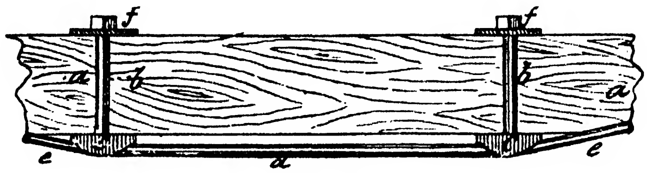


Fig. 88.

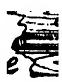


Fig. 84.

Fig. 85.

THE COTTAGE AND THE VILLA GARDENER.

THE LEADING PRINCIPLES AND PRACTICE OF THE ART OF FAMILY GARDENING.

CHAPTER IV.

AT conclusion of last chapter we stated that more could be done in the way of cultivating fancy fruits and vegetables, for which high prices can be obtained, than some may be inclined at first sight to think. And by the exercise of a little ingenuity the appliances necessary for their cultivation can be had at a very small cost. Those of our readers who have seen but little of this kind of work done would be surprised to see the fine fruits, flowers, and fancy vegetables, as cucumber, sea-kale, vegetable marrow and the like, grown in structures and appliances costing but a few shillings, raised by the cotton operatives in Lancashire. As to heating of the glass-houses, we have known a mechanic to make a sheet-iron stove, costing ninepence, which, judiciously contrived as to draught, sufficed to heat a pretty large house at a merely nominal cost. "Where there's a will there's a way." But the way is easier with most than the will to do.

Some Useful Hints on "Making the Most of Things."

If the cottage is situated within reasonable distance of a town, especially if that be a manufacturing one, it is difficult to name anything produced by the soil which cannot be sold quickly and profitably. If there be children grown up, even although young, they can be taught, as we have already suggested, so to cultivate their tiny plots of flowers that nosegays may be made for which there will be found a ready sale. All the family, down even to the little child, can be made to do something which will add to its resources; a child must be very young, for example, who cannot be taught to weed and to gather up odds and ends which help at once to make manure. And this reminds us that manure, so necessary in a garden, and often so difficult to be got, can be largely added to with very little exertion. Thus, every garden should have a compost heap, to which every substance that can decay should be added; and one will be surprised, on beginning a systematic looking out for manuring substances, how abundant they are. In almost every corner there is something to be found which will decay, and that is manure; and little children even can be made, as we have just said, to add to the bulk of the heap. This system of looking out for, gathering up, and collecting together, every decaying substance, has this other advantage also, that it keeps the place tidy: nothing to a well ordered mind is so annoying as to see the neighbourhood of a cottage, or the garden walks and soil, littered here and there with substances all unsightly, and some not very fragrant. A good addition to the compost heap is soot; and the housewife should, when cleaning down the lower part of the chimney, take care to carry it to the heap. Salt also is valuable, and any brine which can be saved from the refuse of the bacon and ham curing process should be added to the heap; and if the garden has not got a small liquid manure tank, the housewife should add all the slops to the heap, a hole being made in its upper surface to receive these. If currant trees are cultivated, of course, as already recommended, the slops, especially those of washing day, should be thrown to their roots, all fruit trees rejoicing in soapsuds given judiciously. One word in conclusion. In the autumn the gardener must take special care to turn his land over as roughly as possible; some do this in an irregular way, but the better system is to throw it up in deep furrows and ridges. Land cannot be too rough for "wintering" purposes; the frost and other atmospheric influences can never act properly on a smooth surface. Only those who have tried the two plans can tell the wonderful difference there is between the soil which has been thoroughly wintered or weathered by being left rough, and that carefully raked over and smoothed, as some do, in order, as they say, to have their garden neat and tidy for the winter.

Cultivation of Flowers by the Cottage Gardener.—Flowers and Vegetables combined.—Flowering Vegetables.—Ornamental and yet Paying Crops.—Some Suggestions as to their Pleasant and Profitable Culture.

We conclude by recommending the cottager, while paying attention to the useful things of the cottage garden, not to neglect those which minister to the beautiful. It is surprising what can be done with a small plot of ground, where attention is paid to its proper laying out, and how beautiful it may become by a combination of flowers and vegetables. In this country we always keep them separate. Now, we should be inclined to recommend the system adopted in some parts of Germany, where flowers are intermixed with vegetables. When this is done with judgment, the effect is exceedingly striking and beautiful, and many of the odd spaces of ground we have already alluded to may be filled up here and there with an attractive flower. These flowers, grown in this way, may yield materials for nosegays, which may be sold. There is one plant which may be said to serve a double purpose—namely, the scarlet bean or runner, which, when grown upon a neatly-made framework of lath, may serve the purpose of screening off some ugly building, as a dust bin or the like. It will form, during a large period of the year, a beautiful object to look upon, whether in leaf, flower, or fruit; while at the same time it affords an abundant supply—for there is scarcely anything we grow in our gardens so prolific —of a most delicious vegetable. As they grow very quickly, the plants should be gone over very quickly,

so as to use the pods before they become too hard. We have called them *scarlet* runners, but in fact this name is not strictly correct, for many beans produce variegated flowers of the most lovely character. We had a fence once, used to screen off an ugly outbuilding, in which the flowers were variegated to such an extent that it was difficult to reckon the varieties. It was the admiration of all who saw it, while the supply of pods for the table seemed to be inexhaustible. By putting in successional sowings—that is, with intervals between them—the flowers, and of course the resulting pods, may be carried over a much longer period of the year than if the seed is put in all at once. We have named this matter more specially, as it may serve to indicate directions in which the cottage garden may be made exceedingly attractive. This is a point not to be despised, for independently of its good influence on the cottagers themselves, it will tend to raise them in the good opinion of others, which will ultimately pay in more than one way. The influence exerted upon the merely material prosperity of a man dependent upon the public opinion of his work, or for the sale of that which he produces, by his showing in the mere details of that work a thoughtfulness and a determination to make the best and the most of things, should not be overlooked as one of the factors which go to make up the sum of his life. The world —meaning in the present case by this term the neighbours—is by no means so thoughtlessly or selfishly inconsiderate as some cynics say it is. Self-help is an important essential indeed, but so also is neighbour-help; and when neighbours see that a man is specially helpful of himself, they are pretty sure to give him some help in this—and that in the best way possible, by buying his produce or giving him work. And a man who is "handy" for himself will be handy for others; and those others, his neighbours, will not be slow in availing themselves of his "handy" work. Handy men are too scarce not to be valued when met with. If a space can be spared, a little summer-house might be erected in the garden, the sparred or latticed sides of which might be covered with the leaves and flowers of scarlet runners, sweet peas, Indian cress, and other creeping, flowering, and fruiting plants.

And a very beautiful object could be made of what might be otherwise very unsightly. The happy combination of the beautiful with the useful in garden cropping can be done much more easily, and it might be done much more frequently, than it is supposed by many to be capable of being done, and that moreover at but little outlay or cost. Thus the more expensive framework for training scarlet runners which we have named may find a very cheap substitute in sticks or branches of trees stuck into the ground at intervals say along the edges of the garden walks. By connecting these with string or galvanised wire, the plants can be trained along from one stake to another. By this arrangement an abundant crop for the table may be obtained, and that, as we may say, without taking up any land. For the space taken up by each stake need not be considered as occupying soil on which any other crop could be grown; and the same may be said of the seeds, for they can be set round the stake in a small ring—say one *good* bean at the ends of the two or cross diameters—and this portion of soil could be got without robbing it from other plants. Another object would also be gained by this arrangement, and one which we have insisted upon as being that which should not be overlooked—namely, an attractive feature in the garden. For festooned, so to say, from stake to stake, the combination of foliage and flowers during a long period of the growth of the plants makes up a sight which will always be admired. And at a later stage, the heaviness of the resulting crop will not be the least satisfactory feature of this method of growing scarlet runners at once for beauty and for profit. For the ready access of sun, light, and air to the plants, effected by the way they are spread, or hung out rather, so to say, from stake to stake, encourages that rapid development of the plants and their consequently following fruiting, which is never met with, can never be met with, when they are huddled together with a large proportion of the plants kept from the influence of the light and air, upon which so much of their fruiting depends (see the plates of Garden Architecture for sketches of methods of training running plants).

By the way, we may here note, while on this to the cottage gardener not unimportant point, that this way of growing scarlet runners may be carried out in more ways than one. Where moderately high and stout stakes can be had in sufficient number, there is nothing to prevent a crop of scarlet runners being grown above the potatoes; forming thus a species of hanging crop or aerial garden. They may be said to be obtained for nothing; for they will borrow but little from the potato crop soil, and as that is sometimes too highly manured, the scarlet runner crop may do good to that of the potatoes. Harm, as a rule, it may be reckoned upon as not likely to do—and the result of the arrangement will be a sight as novel in a cottage garden as it will be beneficial. A hint may be taken from this as to growing other crops along with potatoes. Cabbages are often, for example, grown between the rows. The "tree cabbage," a most prolific grower of leaves for food of pigs, etc., would be the best for the cottage garden if grown in this way. The variety is known, and perhaps most widely, by the name of the "thousand-headed cabbage." "Vegetable marrows" afford an excellent crop for growing between the rows of potatoes.

THE MACHINE MAKER OR GENERAL MACHINIST.

SPECIAL EXAMPLES OF HIS WORK—ITS LEADING TECHNICAL PRINCIPLES AND DETAILS.

CHAPTER VI.

IN the last paragraph of the preceding chapter we stated that the practical machinist of much earlier times than ours got nothing in the way of help from the men of science of their day—could in fact get nothing even if they had looked for it—which, from what we have seen, is just the thing which from lack of time, to say nothing of that of will, they were least likely to do. For the early writers had quite a grand ignorance of the fact that such individuals as *workers* existed—a very natural result of their indifference to the actual work to be done around them. The machinist had, therefore, everything to find out for himself; and what he did find was got, as we have seen, with infinite pains and mental trouble. What we call a "connecting rod" might be represented by the writer or theorist as a line, and a toothed or "spur wheel" by a circle; and the writer or theorist had little concern with any fact—if fact it was, and not a myth, merely—that all promised to work well on paper, or, what was much the same thing, in his imagination. He troubled himself in no wise with what difficulties the "base mechanic" would find when to the mere line of a lever or the curve or circle of a wheel he had, so to say, to give the "life" —a term, by the way, daily used amongst us in practical mechanics and machinery—by which both were to *do* the work the machinist wished them to do. In giving this mechanical life difficulties of a very prosaic kind came up fast and thick, which were never thought of apparently by the early theorist or writer: at least, if thought of, not being deemed worthy of any notice by them in their prelections, certainly not of that special character explaining how they were to be dealt with in such a way as to be of really *useful* service to the practical man. And the task, so truly to call it, of mastering difficulties, which the machinist or (to use the term so generally then employed) the mechanic had to undertake, was not only of the highest degree of severity, but it lasted long, for it was made up not only of a vast variety of details more or less minute, but each detail demanded many and repeated trials before the best way of executing it was discovered and given place to in the workshop, as the best way of working it out,—at all events, if not universally acknowledged as the best, at least admitted to be the nearest approach to the best possible, under the circumstances of the time and of working then existing. And those circumstances were such as for a long time precluded the possibility of arriving at the best way of doing the work connected with the practical construction and making of machines and their various parts. In many cases the best way is not even yet arrived at,—a fact which is evidenced by and lies at the root of the number of devices which are brought out from time to time to make some section or some part more perfect than it has before been.

Conditions under which the Practical Machinists in the Earlier Periods of Modern Work did their Work.

Following up the present line of inquiry, it will be useful here to glance at the conditions with which the early machinists had to contend, and at the deductions from these, which the young technical reader will find to carry with them matter of great practical value. Some of the difficulties with which the early machinists had specially to contend we have already hinted at. But they may all be considered as arising out of three conditions of the materials with which they had to work—namely, weight, strength, and friction.

The theorist or writer who had so long dominated in the region of mechanics—using here the then generally employed term—found it an easy matter so to arrange his diagrams that movements were got out of them, so to say, in the easiest possible way, as such conditions as we have just now stated in no way were taken into account. But the machinist knew in the most convincing of all ways that in designing movements the parts he had to deal with in giving them "mechanical life" possessed weight, which very weight in itself gave rise to mechanical difficulties, for as motion was the result or object, the very movement of a heavy part—itself the cause of motion in another part—demanded a certain amount of force. And a certain amount of force only being supposed to be available, it is obvious that the mere moving of this heavy part lessened the amount of the force he had at command for the doing of the final work designed. So that the practical result was that he could do less work, and this simply because he had to devote so much of it to the moving of the heavy part which in itself was only necessary to communicate a certain movement, or transfer motion from one part to another. The machinist would have been only too glad to have found even the least approach to the condition of matters of the theorist, to whom weight of materials was of no concern. But things being in actual work so vitally and essentially different, his first impulse would be to approach as near as possible to the theorist's position and make his parts as light as possible; for the lighter they were the less would be the amount of the force which they would take, and the more they would leave of it for the work finally to be done, and for which the machine was in fact to have its existence.

But at this point considerations connected with

the second condition of the materials with which the early machinist worked would force themselves into notice. In his desire to save power or force, or, what was the same, to have as much of it as he could to do the final work of the machine, in making his moving part very light he would find that in proportion to this he would make it very weak. Now, from the very first, at least at a very early stage of the art of machine construction, the mechanic would perceive that if there was any one feature which was more essential than another to the working life or the existence of a machine, it was that of strength. For however beautiful, in his estimation, might be the motions, and however accurately and even elegantly—according to the standard of the times—its framework might be designed, if it could not hold together, and with such strength and stability as to do the work without "breaking down," it was worthless for the practical purposes of doing work. And it was in the *doing* of work where all the difference lay between the labours of the theorist or writer and the work of the mechanic. Common sense would indeed show him this. And, as we shall shortly see, this human attribute has a much closer connection with, and a much higher practical and pecuniary value in the actual work of the machinist than it is by many supposed to have.

Now, to gain this essential strength or practical capability to do its work or overcome the resistances which that work created, the machinist would take care to give what is called "strength" enough, by the abundant use of material; and we know that the machines of the early periods of the history of machinery were undoubtedly heavy and clumsy. The early machinist was thus placed between two fires, so to say, or opposite and opposing forces—one demanding lightness in order to save power or force, the other heaviness or weight, to give the strength without which that power or force could not practically be made available in doing the work, as well as care in making or forming it; and it was only after long experience that machinists arrived at that knowledge by which they obtained the maximum of strength with the minimum of material or the lowest weight or mass, and which also showed that the heaviness or weight in did not give strength to a part, but that form and section played an important part in this respect. Some, indeed, have not even yet acquired this knowledge, as may too easily enough be evidenced in examining a widish range of modern mechanism. Some, if not of our earliest machinists, at least of those who flourished a good many years ago—"born engineers," as they are called—seemed to possess this knowledge naturally; the right proportion between the strength which the force or power on the one hand, and the lightness which the saving of it on the other, demanded, seemed to be arrived at by them intuitively. And to such machinists we owe some of our best examples of mechanical parts, both as regards weight or strength and the form or configuration by which that was given. Of the various schools of mechanism which became localised or found a home in various parts of the kingdom, that of Manchester, if not the first established, assuredly the most practical, was notable for the number of so-called "born engineers" which it possessed, and to them we owe possibly the highest examples of this, what some have claimed to be called the "national school of engineering." But it is scarcely necessary here to say, holding or endeavouring to hold the balance evenly as between contending claimants for mechanical precedence, that much as has been done, much as is being done daily, by the "Manchester school" of mechanical engineering, other localities have had a large share in placing it in the secure and highly cultivated condition we on all sides see it to be; and it would not be a difficult matter to prove that there are many other localities throughout the kingdom which have contributed largely to this condition of the art and science,—so much so that the truest way of putting the point is the somewhat tautological phrase that the formation of the national school of engineering has been the work of the nation generally.

Conditions under which the Practical Machinists in the Earlier Periods of Modern Work did their Work (*continued*).

In preceding paragraphs we passed in rapid review some of the points connected with the early times of mechanical engineering, as conveying lessons of some value to the machinist of the present day. And in the latter part of these we took up the subject of the conditions under which the early machinists did their work. From what was given under this head the technical reader would be able to draw some suggestive matter of practical value to him in his study of the general subject. But such information of this useful character as this special subject named above is so well calculated to give is by no means exhausted. A treatise, and by no means a small one, could easily enough be written upon it, and its value to the machinist of the present day it would not be easy to over-estimate; but our space being at the best but limited, we shall confine our remarks to the leading features only of this most suggestive theme.

In a preceding paragraph we pointed out the two conditions of the materials and the forms they had to assume in practical mechanism with which the early machinists had to deal. In their work connected with the third and last condition of those to which we now direct attention, they had difficulties to contend with of the like character to those we have named in connection with the two first. The diagrams of the theorist, considered purely as such, or of the

writers of the works we have already pointedly referred to, would show clearly enough—and for that matter it might be absolutely accurate—how by a certain combination of lines and circles certain motions would be produced, if those took form in a material way in the shape of links, connecting-rods, wheels and pulleys—those placed under the influence of a certain power or force. But to fit them for this influence involved considerations which the practical machinist was, as in the other instances we have named, compelled to take into account. For in putting the parts together, he found that when in motion those which had sliding or rubbing rectilineal, and those which had revolving or circular motion, were in their motions opposed by a something to which the name of "friction" has been given, and to overcome which was just as necessary as to find a force or power to do the work or overcome its resistances. So potent was this power that he was inclined to look upon the work done as being represented by the friction induced in the moving parts employed to do it.

To lessen the loss of the force or power at his command, the early machinist was compelled to arrange the parts of his machine which had motion so that they could work with the least amount of friction; and as links or levers had to be connected with or jointed to each other, wheels and pulleys to be hung on their axles, the different forms of pins, studs, joints, spindles, shafts, and the beds or bearings by which they were held together, supported, moved, or worked, were devised. And however easy it might be to design them—and this existed in varying degrees of difficulty—it was by no means an easy thing to construct them or carry them out into practice. The very lack, indeed, of the appliances by which mechanical work was done, and to which we have had occasion to refer as a most important factor in the question of mechanical progress, made it so difficult a work that for long all the parts we have named were of the roughest and rudest kind. And in examining the work of the "old masters" in mechanism, it is "sad to see" how painfully difficult it was for them to secure even passably good work. When we state that work not one whit better is still to be met with in some machines made in the present day, and in face of all the experience of the past, which is as open to them as to others, and in view of the command of all the tools and machine tools within their reach, the technical reader should be able to perceive the, to him, practical value of the lesson which the fact is so well designed to teach.

The Application of Theory or Science to the Construction of and the Forms used by the Early Machinists.

We now, in our rapid review of the early progress of mechanism, arrive at the period in which, taking up the machines and the forces which their component parts had assumed as entirely owing to the labours of the early machinists, men of science turned their attention to the thorough investigation of mechanical problems and work, and deduced formulæ and recorded rules and calculations of great value to the practical machinist in his work.

In meeting the difficulties connected with the materials which they had to use, the early machinists gradually brought into existence certain forms in what may be called the stable parts or framework of machines, and in the movable parts or motions. Those in point of numbers were not many, and as each part had a certain definite duty to perform, they rapidly became stereotyped, so to say, and were again and again used whenever the peculiar circumstances of the machines demanded their employment. But as the necessities of various trades and industrial processes gave rise to "order" after "order" for the machinist to supply machines calculated to aid or to supersede manual labour, the ability to design and the skill to construct increased in even a quicker ratio than the demand for their exercise. But the parts which we have named as having become stereotyped or established in use did not increase in anything like the same proportion. In point of fact, they remained almost stationary as regards numbers. What progress was made was only or chiefly in greater care being taken in their construction and their alteration in some parts of their form in accordance with the increasing demands for what is called "taste" or elegance. And it is curious and most suggestive to note that, as in the carefulness in execution or construction, including fitting as well as making, progress could be made up to a certain point, and that a very limited one in its range, where handicraft tools and skill were alone employed, the demand for a class of work higher still both in efficiency and in the economy of time brought into existence those machine tools which in themselves afford, perhaps, even more striking examples of what the modern machinist has done, and can do, than the very machines themselves which are made by these means. The class of machines, for example, which have been brought out to meet the demand for flat or rubbing surfaces absolutely "true," or as near "mechanical truth" as can be obtained afford instances of mechanical ability to design, and also as of consequence to construct, of a very remarkable character, well worthy the patient notice of the technical reader. The dual connection here named he should also take special note of. For it is obvious that a machine tool which is to give mechanical truth to a part of another machine which is in process of being made must itself be made with great accuracy—must, in fact, be true itself, for truth can never be the result of error.

THE IRON MAKER.

The Details of his Work and the Principles of its Processes.

CHAPTER XIII.

Mechanism of the Blowing Engine (*continued*).

Continuing our description of the mechanism of the blowing or blast engine (fig. 4, Plate CLXVII.), we note that in the upper movement of the piston the position of the valves relative to it is changed; and we now see the valve *i* or *g* at bottom of chamber *d d* open as at *j*, giving access to the air from chamber *d d*, as shown by the arrow 5. The valve at upper end of chamber *d d* is now closed, as at *k*, preventing the air above the piston *b* from passing from the upper space *a a* of cylinder to the air chamber *d d*. We see now how the upper and lower parts of the cylinder above and below the piston are supplied alternately with fresh air from the chamber *d d*, this obtaining its supply from the external atmosphere through the orifice or pipe *e*.

We have now to trace the course of the air thus supplied alternately to the spaces above, as *a a*, fig. 4, Plate CLXVII., and below, as *a' a'*, of the cylinder, as it is impelled by the piston moving alternately in the direction of the arrows 3, 4′ and 7. On the side of cylinder *a a a a*, opposite to *f g*, there is another chamber, *l l*, which is also provided with two valves, one at top, as at *m*, the other at bottom, as at *n*. Supposing the piston *b* to be moving downwards: the air has previously been supplied to the under part, *a' a'*, of the cylinder from the chamber *d d*, through the valve at *g* which opens as at *j* in the upward movement of the piston *b*, as already explained. As the piston *b* descends the valve *n* opens, as shown in the diagram at *j*, while the valve *m* closes, as at *k*. A stream of air is thus, by the piston *b*, pressing downwards, impelled or forced through the open orifice *j* into the interior of the chamber *l l*, while the air previously forced into it is prevented from passing out of it by the closing of the upper valve *m*, as shown at *k*. When the movement of the cylinder is reversed the upper valve at *m* is opened, as at *h*, the lower at *n* closed, as at *i*, and the air at the upper side *a a* of the piston *b b* is forced through the valve *m*, as at *h*, into the chamber *l l*, while air from it is prevented from passing out by the orifice at *n*, by its valve closing as at *i*. The only way by which the air thus forced into the chamber *l l* can pass out of it is by the pipe *o*, as shown by the arrow *o*, and this pipe leads directly to the blast furnace.

Action of the Blast in a Blowing Engine.

We thus, in tracing the action of the blast or blowing cylinder and the course of the air impelled by its piston in the opposite and contrary direction from top to bottom, and *vice versâ*—find a continual changing into opposite and contrary positions of the valves *h* (*f*) and *i* (*g*) and *k* (*m*) and *j* (*n*). Thus, while the piston *b* is descending, the valve *h* (*f*) is open and its opposite valve *k* (*m*) is closed; and when the valve *j* (*n*) is open, its opposite valve *i* (*g*) is closed. And the same relative condition is maintained when the piston moves upward: the valve *g* (represented by *j*) is open, while the opposite valve, *n* (represented by *i*) is closed; the valve *f* (represented by *h*) is closed, while the opposite valve *m* (represented by *k*) is open. These relative positions are shown in the lower diagram, which is that assumed when the piston *b* is descending, the upper part of cylinder *a a* being filled with air through the valve *h*, the air in the space *a' a'* below the piston being forced through the valve orifice *j* into the chamber *l l*.

There is thus a continual interchange of position of valves and piston; resulting in a continual supply of air to the chamber *l l*, and through the pipe *o* to the blast furnace interior. But although this supply of air to *l l* is constantly kept up, the passage through the delivery pipe is not uniform in the velocity with which it is impelled by the force of the piston ascending and descending the cylinder. This is evident when we consider that the motion of the piston is alternating, and that there must be a halt or stoppage in this, at the point where the motion of the piston is about to change from the down to the up direction, or *vice versâ*. This halt, so to call it, is in practice very brief, but it results in a decided influence upon the uniformity of the blast. A like condition of circumstances arises in the use of a force pump in supplying, for example, a fire engine with water to be forced through the hose or flexible pipe. The stream of water forced through it, while constantly kept up, is not uniform in its blow; but a lessening of its velocity is coincident with each change in the direction of the plunger of the pump. To insure uniformity of discharge from or flow along the hose, the water is delivered from the pump into a large air-tight receptacle termed an air vessel. The delivery pipe is laid near to the bottom of this, deriving its supply from the water in the lower part of the air vessel; while the air in the upper part of the receptacle, being compressed in the upper space by the volume of water occupying the lower, presses like a spring upon the surface of the water, and thus forces it through the delivery pipe in a stream of uniform bulk and velocity. In the blast furnace blowing cylinder, which we have just described, a similar effect, or nearly similar, is produced by making the delivery pipe *o* of considerable diameter and length, so that it forms a large chamber which, although receiving a succession of volumes of air at intervals only, acts as a space in which the separate

volumes of air delivered to it are, so to say, blended together that they reach the blast furnace in a stream or current possessed of practically uniform velocity and pressure. This pressure is obviously given to the current of air passing along the delivery pipe *o* by the great force with which the piston *b* is forced down or lifted up in the cylinder *a a*, fig. 4, Plate CLXVII.; and the amount of pressure is such that it is able to support a column of water equivalent to 2 to 5 lb. pressure per square inch.

The diagram in fig. 4, Plate CLXVII., illustrates only a general principle upon which the blast of air to the delivery pipe *o* is produced by the ultimate movement up and down of the piston *b* in the cylinder *a a*. It does not attempt to show the arrangement and mechanical construction of the cylinder, its valves and chambers. These vary with the varying notions of engineers and machinists, the great object aimed at in all being the supply of air to the blast furnace in a current as uniform as possible—and this effected by movements in the cylinder and valves so that the great and continuously created shocks arising from the quick opening and shutting of the valves of so large an area, and subjected to so great a pressure by the piston, shall be reduced to a minimum. How great the effect of those constantly recurring shocks can only be realised by a practical acquaintance with the working of blast engines. When the valves are not properly adjusted, or the mechanical arrangements are defective, the noise and vibration present in the blowing engine house are somewhat bewildering, if not alarming, to the inexperienced. The kind of valves to be used, their arrangement in relation to the cylinder and its chambers, their construction or fitting, the velocity with which they should be worked, are points of detail in connection with blowing engines which have furnished a fruitful source of discussion amongst engineers and machinists devoted to the design and construction of iron-making machinery and appliances. Although the centrifugal revolving fan or fanners are used so universally by iron founders, they may be said to be altogether excluded from blast furnace work, although it would appear at first sight that the advantages of their continuous circular compared with the alternating reciprocatory movement of the blowing cylinder would be so great—if in nothing else than in the uniform character of the blast produced by it—as to have insured its general use, to the exclusion of its more ponderous and complicated mechanism. But, as we have said, the fan is never practically used in blast furnace work, the blowing cylinder universally. The only exception to this is perhaps met with in the case of the form of blower known as Root's Ventilator, in which the motion is, like that of the fan, continuous and circular, but in which the current is produced by totally different mechanical arrangements.

Temperature of the Air blown into the Blast Furnace in "Cold" and "Hot Blasts."

For long after the introduction of the modern blowing engine, which gave a power of producing higher and more equally sustained temperatures in the blast furnace than had before been within reach of the iron maker, the air delivered to the furnace was at the same temperature, or thereabouts, as the ordinary air from which the blast cylinder derived its supply. In other words, the blast was a "cold blast." Most of our readers will have an acquaintance with the term "hot blast" used in the technical language of "The Iron Maker." To those who know but little more than the term, we now explain what it means. Up to a period but a trifle over half a century ago, the iron makers universally—for no exception is known—held a decided opinion that the colder the air of the blast the larger the produce of the blast furnace. This was apparently corroborated by, if indeed the opinion was not based on the fact that the produce of blast furnaces was higher in the cold weather of winter than with the warmer temperature prevalent in summer. No one disputed this fact, nor apparently conceived that there was any other reason for its existence than that now named. Hence, efforts were made, and in some instances special appliances used, such as passing the air to supply the blast in contact with cold water, to cool the heated summer air as much as possible. So far as the history of the trade tells us, no one seemed to conjecture that there might be some other cause for the greater produce of blast-furnace working in winter than the colder atmosphere then usually existing. It is now, however, known that the real cause of the greater efficiency of a cold winter blast than a hot summer one was that the winter air was much freer from moisture than the summer air. Some of our readers may express surprise at this fact in physics; but if they will refer to any paper which takes up the subject of "artificial drying," they will find it explained, and will understand how it is that the warmer the summer air is the greater is its capacity for taking up and holding moisture, which is supplied in abundance from the soil and other sources.

It was, then, the dryness of the colder winter as compared with the moist state of the hotter summer air which gave the value to the former for blast-furnace or iron-making purposes. But no one seemed, to have discovered this, or, if so, had made any practical application of it. In the year 1829, however, a Mr. Beaumont Neilson, at the time a manager of the gas works at Glasgow, conceived the idea of warming or heating the air which was to be passed into the blast furnace by the blowing machine by means of a special furnace applied which intervened between the blowing engine and the blast furnace.

THE STEEL MAKER.

HE DETAILS OF HIS WORK—THE PRINCIPLES OF ITS PROCESSES—THE QUALITIES AND CHARACTERISTICS OF ITS PRODUCTS.

CHAPTER XIII.

Bessemer Pig Iron.—Cast Iron specially adapted for the Bessemer Process (*continued*).

WE have, in the preceding chapter, stated that of all the ores used in this country those of the celebrated "Cleveland" or Yorkshire district might be said to have the pre-eminence of being amongst, if not actually, the most debased with phosphorus and sulphur. Yet, so complete has been the success of the Thomas-Gilchrist method of dephosphorising and desulphurising those Cleveland ores debased so highly with these elements, that tons upon tons of good Bessemer steel are now being made daily and rolled into "rails" at the celebrated Eston works of Bolckow, Vaughan, & Co., near Middlesbrough, direct from the "Cleveland ore" cast iron produced in the blast furnaces. In cases where the Thomas-Gilchrist process of dephosphorising is not adopted, and where the iron is to be cast of the quality best calculated for the making of the Bessemer steel, care is necessary to insure a mixture of ores or to use a quality of ore such as the hæmatite ore from which the Bessemer pig is made, in order to secure a cast iron for re-melting as free from phosphorus and sulphur as possible. How this quality of metal can be in great measure obtained by judicious care, we shall presently see. In other cases the direct process may not be attainable, and the roundabout, or cupola, or re-melting method remains absolutely necessary, from the circumstance that the steel works may be purely such, the producing of cast iron from the crude ore by the ordinary blast furnace not forming a part of the same establishment. In this case, unless cast iron of good quality—that is, free from phosphorus and sulphur—is purchased, re-melting them in the cupola is an essential part of the process. These qualities of deteriorated or debased pigs are generally mixed with spiegeleisen and ferro-manganese, in order to secure the proper percentage of carbon and manganese. We shall presently have more to say on those two constituents of mild steel, in referring, as we are now about to do, to some of the difficulties attendant upon the introduction of the Bessemer process; in noticing which some points of interest on the subject of steel will incidentally arise.

In carrying out certain processes it is often found that the results vary, and this in such a way, so unexpected, uncertain, or capricious, that the discoverer or inventor is fairly puzzled; and so puzzled that it is sometimes long before he finds the "riddle" out—not seldom never finds it out at all. It is too often assumed that the materials employed or operated upon are homogeneous and alike, while the reality is that they are very different; or may be placed in such conditions that an action takes place which changes their direction and renders them unfitted for the process. On the other hand, the process, while thought to be as good for any one class of material as for another — that is, for any one class of several classes—is in reality only adapted to, and can show its powers when operating only upon or through one class. This latter was the position of the Bessemer process. The iron and steel trade can furnish more than one example of this truth,—a process which has been successful while operating upon *the one* material for which it was alone adapted, failing and always failing when it was applied to other materials not adapted to it. If the "mountain, therefore, would not come to Mahomet, Mahomet must go to the mountain." The Bessemer process evidently possessed a potentiality of power—so somewhat tautologically to put it—capable of doing great things from some material, if that for which this process was fitted could be found. If it could not succeed with the whole of the generally used classes of iron ores, could the one ore for which it was fitted be discovered? The point involved in this question was one of immense importance, considering the interests at stake; and by one of those fortunate circumstances with which the history not only of our iron and steel, but of other manufactures, may be said to abound, it was answered, and completely,—circumstances or conditions which have always existed ready to be availed of, and often easily and directly applied, waiting for the hour at which they were most urgently required, and the man by whom they could be so applied. The question itself, after all, was one of extreme simplicity. If the ordinary pigs of iron, or what may be called the average quality of cast-iron pigs, obtained from the ores of the general mines of the country, do not, when subjected to the action of what we may here call the Bessemer blast, operating through the agency of the Bessemer converter, yield the desired product of a metal so free from sulphur and phosphorus that it can be "worked," and this from the fact that the ordinary pig iron is so "debased" with impurities that the process cannot eliminate them, is it possible to procure pig iron either so free from debasing constituents or in such a condition that the Bessemer process by its action produces an iron practically free from those deteriorating substances? In the pig iron of the Cleator district, made from the red hæmatite ore, the required conditions were met with; for it was so largely free from debasing constituents that it was exceedingly well adapted to the Bessemer blast and converter. So much so, and to such an extent was it employed by Sir Henry Bessemer and those working under licence

from him that pig iron made from the "red hæmatite" ore of the Cleator district, and what are known to the trade as "Bessemer pigs," became convertible or synonymous terms—only that the latter phrase was the one really used to designate the pig iron of the district, the "Bessemer pigs" being made almost exclusively as they were extensively from the Cleator ores. How happily the discovery was made of the applicability of those ores to the peculiarities of the Bessemer process may be gathered from this statement,—that as compared with the average of no fewer than thirty high-class pig irons made from the ordinary ores in use throughout the kingdom, the Cleator ores contain but little more than 50 per cent. of sulphur, and less than 25 per cent. of phosphorus—carbon and silicon being slightly in excess. But taking the low-priced and commonly used pig iron of the Cleveland district, while the sulphur in that of the Cleveland district and the carbon and the silicon were about the same as just stated, the difference as regards the phosphorus was still more in favour of the Cleator red hæmatite pigs, as they only contained about 6 per cent. in place of 25 per cent. This adaptation of the Cleator pig irons to the capabilities of the Bessemer process was, as we have said, one of the happy hits made by what men called chance or good fortune; it was not traced out, followed up, and made by theoretical considerations or scientific deductions—as other discoveries in the iron trade have been made. Those Cleator or red hæmatite ores fell into their places, as Mr. Williams inclines to think, by a "process resembling natural selection," which here, as in the animal and vegetable world, has determined the survival of the fittest.

Spiegeleisen and Ferro-Manganese in the Bessemer Process.

We have referred to the use of spiegeleisen and ferro-manganese along with the special quality of pig iron used in the converter in the making of steel on the Bessemer process; these substances being used in order to get in the steel the required percentage of carbon and manganese. We have in a preceding chapter shown the important part the element of carbon plays in the constitution of steel, but it will be well here again briefly to refer to this important point. Important in steel as the element of carbon is, it will surprise many of our readers to find how exceedingly small the percentage of this element or constituent is in steels of all qualities; and still greater will be his surprise to note how exceedingly minute the difference is between that proportion of carbon which gives a certain quality of steel, and that other proportion of carbon which gives a quality of steel in some cases of a totally different character as regards its constructive peculiarities. The qualities which wrought iron possesses are well known to every one: it can be hammered when heated, and drawn out or greatly extended in length. To these qualities of malleability and ductility a third quality and a highly useful one is added—namely, that of considerable tensile strength—that is, a capability to resist the force of tension which tends, in drawing out the fibres of the metal, to separate or tear them asunder. Now, by altering the condition of the iron—by "adjusting," so to use this expression, the percentage of "carbon" present or to be present in it—we can bring about changes more or less decided, and some of them very remarkable in the constructive influences, in the character or quality of the metal. We can thus increase to a large extent the quality of tensile strength—that is, give the metal a capability to resist strains tending to pull it asunder—by adding carbon to the iron. And what we have above alluded to—namely, how very minute are the actual amounts or percentages of carbon required in all cases—will be seen when we state that this difference in the qualities of the iron just alluded to can be secured by the addition of so small a percentage of carbon as 1 per cent. When this percentage is present in iron we have a steel which has an increased tensile strength as compared with the wrought iron; this tensile strength being equal, on an average of specimens, to a resistance of a pulling strain of sixty tons per square inch of section. But while we have increased the tensile strength, or its power of resisting a pulling strain, we have reduced the ductility of the metal—so much so that it cannot be used for many constructive purposes. And from being tough, as was the iron up to a certain limit, we have got by this small addition of carbon a metal brittle and easily broken, to a greater or less extent. At the same time the metal has received other properties, for it is capable of being tempered or hardened, so that it can take or receive a fine cutting edge; in other words, it has the properties of the metal we know by the popular term of steel.

To obtain, then, the different constructive properties in the mild steels produced by the Bessemer process, it is necessary so to proportion the percentage of carbon as to give the metal precisely the qualities or characteristics which are required; and it is in doing this that the very minute differences between the percentage present in or given to different qualities of metals, and to which as a most striking and suggestive fact in metallurgy we have referred, is observable. Thus, a steel of great ductility, that is, capable of being drawn out, but of a low tensile strength, or a small capability to resist a pulling or drawing-out strain, is obtained with so small a percentage as one-thousandth part of carbon.

THE FARMER AS A TECHNICAL WORKMAN.

His Tools, Implements, Machines and Materials. —The Principles of his Work in its Various Departments.

CHAPTER IX.

Chemistry of the Soil as affecting its Cultivation (*continued*).

At the conclusion of the preceding chapter we offered some remarks as to the character and nature of the soil used as a seed-bed for farm crops; and we concluded by stating that, although we did not practically know the depth to which plant roots could descend into the soil, there was but little fear of our giving a depth of cultivated soil too great, even though we now had at command steam power to aid us in soil stirring. It is, however, gratifying to know that we possess machinery worked by steam capable of giving us everywhere a depth of porous soil which, with few exceptions, is not at present to be found in the farming of Great Britain. And it is on the further and fuller development of this mechanical aid that we do not hesitate to say lies the future of the great extension of agricultural improvement, which we fully believe will be carried out when more correct views of the "situation" are held, we do not say by farmers, but by other branches of the community, who will see clearer than they see now, how there can be no national work of greater importance than that which will so largely increase the national food resources. Many farmers do not require to be convinced of this; but unfortunately, while they would gladly do their share of the work connected with this extension of productive farming, they have not the means at disposal. When the more enlightened views to which we have alluded are nationally held, we shall see capital put into farming in a very different and infinitely more efficient way than it now is. Meanwhile, while steam power is so necessary to insure all the advantages of this increased power of the soil to produce food, much can be done and is being done to gain some of the advantages of deep culture by the designing and use of implements capable of being worked by power at the command of every one. This deep or porous soil, in which lies so much of the increased productive power of the future, cannot, we say, be too deep. If the plants do not require to go down to its limit in search of food, they will not; but some may require to do so, and under the condition we advocate there will be no hindrance to their doing it. If there be a magazine, as there assuredly is, of fertilisers below our soil, which the deep stirring of it can only unlock, it seems, to say the least of it, but a stupid thing to do, not to open it up, so that we can use it, if we may, or as all science is teaching us, if we must, in order to increase our food supplies. And, we again repeat, steam cultivating mechanism, in its greatly improved condition, gives us the power so to unlock this treasure of fertility, now practically closed to the British farmer.

Porosity of the Soil.—Germination of Seed.—Its Relation to the Temperature of Soil.

This porosity of the soil has the closest relation to the germinating of the seed, and in connection with what we have said above is essential to the farmer and the mechanic who helps him to obtain it. To germinate properly, the seed must not be exposed to the action of light—it must be kept in a dark condition. And yet, while it is so maintained, it is just as essential that the atmospheric influences penetrate to and act upon it. Unless they do so the germination proper will not take place, the root will not penetrate into the soil below, nor the plant germ protrude itself through the soil above; nor the changes go on which transform the starchy matter stored up in the seed into the sugar essential for the promotion of plant life. But a porous soil answers all the conditions.

In one sense cultivation of the soil may be said to be the promotion and the maintenance of its proper temperature. To secure this, porosity in it is essential. Where stagnant water or moisture exists, the temperature of the soil near to or surrounding it must always be low. And a low temperature simply means a failure of the, or a failing, crop. A surface of soil more or less hardened is one favourable to the retention of wet, which collects and remains there a longer or shorter time. And even when the method of cultivation adopted pulverises the upper soil, but only, as nearly all methods in use do, to such a small depth that it is a mere scratching of the surface, the water from rain or melted snow may not remain on the surface, but descend; still it can only descend for a short distance, and be only a little removed from a surface-lying condition. In either case evaporation takes place, and, as our readers know, evaporation is always accompanied, or rather followed, by the production of cold. It is the main object of under drainage of soil to prevent this; but drainage only does half its work if the soil be not porous, and to a great depth. And it may be fairly questioned whether, if our soils were rendered thoroughly porous to a great depth—far, we mean, in excess of the mere surface scratching of the usual method—the necessity for drainage would exist. Certain it is that the plan of extensive drainage now adopted would be capable of such modification in the way of reduction, that a great saving in cost would be the result if this deep stirring of the soil were carried out.

Evils arising from Defective Drainage.—Exhaling or Evaporative Power of Plants.

Stagnant water in soil not only tends to reduce its temperature by evaporation, but it obviously pre-

vents the air from having access to it. And this accession of air, as we have shown, is essential to the due performance of the function of the plant both in germination and growth. Another point is closely connected with that to which we have now referred—namely, the exhaling or evaporative powers of plants. Few, comparatively, have any correct conception of the weight of water which the vegetation of trees and plants draws from the soil and exhales into the atmosphere. The eucalyptus, for example, amongst trees is remarkable for its powers in this way: so much so that its cultivation is being rapidly extended in marshy and malarious districts, chiefly on account of the large amount of water it withdraws from the soil, acting as a natural drainer. The sunflower exhales moisture to the extent of from a pound and a quarter to two pounds a day of twelve hours, and an acre of corn as much as a ton of water. Equal diffusion of the moisture of a soil is an essential to its equal diffusion amongst the plants grown in a field; so that germination and growth may go on regularly and healthily—a result only obtainable by equal and deep stirring of the soil; and the supplies maintained in the lower strata help to keep up the supply of moisture which the plants demand. The deposition of dew—so powerful in the maintenance of healthy and vigorous vegetation—is greatly promoted by the porosity of the soil. A porous soil radiates heat more freely than one hard and impervious, and the heat taken up during the day is quickly sent off from its surface, and cooling taking place, the dews are deposited in a ratio proportionate to the difference between the temperature of the soil and that of the surrounding air. Hence we find in practice that a porous soil is always better refreshed with dews than one in an opposite condition.

Influence of a deeply stirred Porous Soil in preventing the Growth and Development of Weeds.

Finally, the power of a porous, deeply stirred soil on weed growth remains to be noticed. It is not necessary here to say much on the destructive power of weeds in drawing from the soil the fertilising constituents which should be given to the plants specially cultivated upon it. This department will receive due attention in proper course. It is scarcely an exaggeration to say that in many fields badly cultivated as much, if not more, of the fertilising constituents present in the soil is given to the weeds as is given to the crops. And let the fact be explained as it may—and it could, did space suffice, be explained here—it remains indisputable that weeds do not appear so numerously and grow so freely in porous, deeply-stirred soil as they do in that which is in the opposite condition. This may be said to arise from the working of the soil, a necessary part of the system of deep culture, as much as from any special and direct influence which a porous soil as such exercises upon weed growth. But it matters little whether this be so or not: the practical fact remains that weeds do not grow either so numerously or vigorously in a porous, deep-stirred soil, as in one the conditions of which are the reverse.

We have thus gone over the various points which influence the question of land culture. A knowledge of them is absolutely essential to the farmer, as well as to the mechanic who proposes to help him in applying mechanism to the cultivation of land. Much as has been done of late years in the way of improving the cultivation of land by the application of steam-worked mechanism, we have no hesitation in saying that much more would have been done had the farmer and the mechanic worked more in combination with each other, the deficiencies of the one being made good by the acquirements of the other; and had mechanics generally, and those specially who were interested in the application of mechanism to agriculture, given close attention to the study of the points to which in this chapter we have drawn special attention, and others to which we shall have occasion yet to refer. It is truth to say—what we have said before, and it is well worthy of repetition—that no mechanism designed to effect a given work can be successful unless a thorough knowledge of the conditions of that work be had and applied. Yet the opposite of this is too often the case. We have said—and the vast importance of the subject justifies its repetition—that the future increase in the fertility of the soil lies in the application of mechanism in a way much more direct and systematic than that yet adopted. A wide field, therefore, lies before the farmer and the practical mechanic for the exercise of their knowledge, skill, and ingenuity in solving the problem which the question involves. This problem will never, we venture to say, be solved by any one who is ignorant of its conditions. We should, therefore, have been wholly failing in duty had we neglected to place it before our readers, who may be believed to be practically interested in the subject.

Soils.—Their Leading Characteristics.

A very slight acquaintance with farming life and work is required to point out, to the reader beginning to study it, the fact that there is a great diversity between the characteristic features of soils. This, indeed, may be learned on examination even of the tiniest gardens in different localities, town and suburban; and may, in fact, be traced in larger areas, a moderate-sized field giving examples of more than one class or quality of soil. This important department will engage our attention in a succeeding chapter, in which their chemical as well as their mechanical peculiarities will be examined and described. It is the latter alone with which we have here to deal.

THE CABINET MAKER.

The Technical Details, and the Principles affecting the Design of his Work.

CHAPTER III.

Practical Importance of the Confusion of Ideas arising from the Generally Accepted or Popular Meaning of the Term "Design."

The point is one of great importance—not being merely a play upon words, as some may think our remarks to be. If the pupil reader, with the aid of what has been here given, and what otherwise will be, in papers in this work in which drawing and design applied to various materials are treated of, will only think the matter well over, he will perceive that, so far from being a mere trifling about words or terms, what has been said involves principles or considerations of the highest import, closely concerning the true interests of the art of industrial ornamental design. One of the ablest masters, as he has been one of the most practical teachers of artistic design as applied to industry, in discussing with the writer of these lines the past work and the future prospects of art manufacture, remarked that he knew of nothing which had so greatly retarded the progress of this as the unfortunate—so he termed it—name "schools of *design*," which had been given to those institutions the object of which was to teach the principles of artistic drawing and to show their application to manufacture of all kinds. This term has arisen from the fact that it was borrowed from the French term *dessein*, with a most unfortunate misconception of the true meaning of the word.

The term or name "school of design" has, however, got so thoroughly naturalised amongst us, that it is hopeless to expect that it will be changed for one much more definite, or rather, so definite that it will convey precisely, and no more nor less than, what is truly involved in the subject. "Artistic design," "ornamental design," would be terms so far definite that no one could possibly confound them with such a term as "constructive design," to which class of work we have shown that the term design is as truly applicable as to artistic design. But it would have been better had a name or term still more definite in its meaning been applied, such as "artistic drawing" or "ornamental drawing" or "art drawing," or still more simple, "drawing." Few but know what drawing is; but seeing that there is more than one kind of drawing, such as mechanical or geometrical drawing, all obscurity would have been, and would be, avoided if certain of the terms above named—"artistic drawing" or "ornamental drawing" or possibly as better "decorative drawing"—had been daily, or were used. What remains, now that the term schools of "design" is so crystallised or solidified in our language, is to indoctrinate the pupils as completely as possible into the true meaning of the term "design" and all that this meaning involves.

The Term "Design" as involving a directly Practical Purpose.

We have said that the term design involves a "purpose." Much, very much, of the progress of the pupil in the application of the principles and practice of artistic drawing or ornamental drawing to the work of cabinet making—or, indeed, to that of any other branch of art manufacture so called—depends upon his thoroughly understanding all that is involved in this word "purpose." If he intends to work at all, that work must be preceded by, based or founded in fact upon, something which he proposes or purposes. Let him keep this purpose steadily in view. What, then, is it that the cabinet maker and upholsterer—for it is difficult to separate the two callings—purposes to do? Put in few words, it is this. To make, in the first place, articles of furniture which will serve the purposes of that *utility* which is the very reason of their existence, the primary impulse which brings them into being. The second purpose he has in view is to give to such useful articles or objects such characteristics as will make them pleasant for the eye to look upon. We prefer to put the point in these words rather than to use the term "beautiful," which is so much disputed—or the phrase "to gratify the taste"—the latter being not a whit less disputed than the former term.

Ornament and Construction.

This effect, which we thus call pleasing to look upon, or pleasant to the eye, is obtained by two added features: one is "form," the other "colour." When these are added we say that the "constructed" article or object is "ornamented." And we then come to the phrase about which much has been both spoken and written—"ornamented construction." As illustrative of the confusion of ideas which has clustered most unfortunately round what is called "art," it is worthy of distinct mention here that this term "ornamented construction" has been applied with strange persistency to define what *architecture* is. Just as if buildings were the only objects in which construction was concerned; as if we did not construct other objects—such as a chair, or, to take one larger and more expensive, though not a whit more useful in its way than a chair is—a railway bridge or a scaffolding. We thus perceive what the "purpose" of the cabinet maker and upholsterer is in connection with what is generally called the furniture of a house. He has, or ought to have, a distinct purpose always in view—that is, he must "purpose" to do something. What he has to do we see, and it is beyond all doubt a dual

or twofold purpose. He has to consider the claims of the useful—of utility—and also those of what, for lack of a more precise term, we call here ornamental.

Purpose in the Designs of the Cabinet Maker.

It seems to be but a paradoxical way of putting the point to say, in respect of the first of those claims upon his "purpose," that the cabinet maker must make his objects serviceable for the work they have to do, or they cannot be useful. This, however, is so far from being a mere play upon words, that it lies at the very root of the work to be done—although beyond a doubt this inherent importance is too often overlooked; and so overlooked that while the second of the claims—that of ornament—is so fully met that the designer may arrive at an arrangement of form and colour so effective as on all sides to be freely admitted that as an artistic design it was good, yet the object so ornamented might be utterly worthless for all purposes of utility. What conclusion, then, is to be drawn from this? Mainly, the important canon or rule that *all added ornament, whether of colour or of form, or as it may be otherwise termed "decoration," or of both, must be subservient to the purposes of utility.* This, as we have said—and it cannot be too thoroughly apprehended by the young cabinet maker—is the very reason of the existence of the object, the very, and strictly speaking, the only purpose for which it is made. A chair, if it suits the purpose for which it is made, fulfils its office perfectly so far as construction is concerned; and its owner can dispense with ornament being added to it, without any actual loss. It is only when a higher value is attached to the object, and something gained in another way, that ornament is added to it.

Utility an Indispensable Feature in the Work of the Cabinet Maker.

Utility is therefore simply essential to be considered; and that being once secured, attention can then be turned to ornament. What, then, does utility convey? Clearly, two things: the object must possess "strength" to enable it to stand all the pressure put upon it—in other words, it must be able to be used so as to stand "usage"; secondly, it must be made to serve the purposes of "convenience" in use. Strength and convenience, or to concrete them into a single word, "fitness" for the purpose in view, must be duly considered in aiming at the utility of an object. A chair, for example, might be made strong enough to resist the sudden descent upon its seat of the weight of a giant, or a Daniel Lambert, and to withstand every kind of cross strain he could put upon it; and yet it might be so made that it would take a giant's strength to move it from one place to another or even to lift it. Mobility thus forms a feature in the utility of certain objects of furniture, and gives rise to its two great classes: first, those articles which are moved, or can be moved, easily from place to place in the room; and second, those which, although not absolutely fixed, are so intended to remain in one position, as a rule, that they are termed fixed articles or objects of furniture.

Fitness and Convenience Points to be considered in Furniture Design.—The Work of the Old Cabinet Makers.

"Fitness" for the purpose for which they are made, "convenience" for the way in which they are used, are, therefore, the essential characteristics of objects or articles of furniture. And these two may be summed up in the one word "utility." And this attribute the objects must possess, otherwise they may as well not be made. How far the attainment of this the primary purpose of all objects of furniture is secured, we have but to look around us with careful observation to see. The more this examination is made with scrupulous care and with a mind unbiassed by any trade or personal prejudices, the more clearly, we fear, will the truth be made known that in but too wide a class of furniture designing and making, and in too great a variety of objects, the attainment of the attribute we have seen to be essential is far from being secured. In very many cases, indeed, this essential attribute of utility is attempted to be secured, but in a very perfunctory and careless way; in not a few it may be said with all safety it is not secured at all. Many articles of furniture are daily disposed of, in which, for the strength which gives fitness we have but flimsiness, for thorough convenience only clumsiness. Utility in such cases, in the practical sense of the term, does not exist, or only in the most straitened and narrow of ways. To how much of the furniture of the present day is the saying thoroughly applicable—"they are made to sell"? To be made for use has in no wise been considered by the maker. We may sneer at the inelegant clumsiness of the furniture of our forefathers, and contrast it with complacency with the trim, the pretty, and "genteel" (?) articles of our own day. But the comparison, if made with an honest purpose, is altogether in favour of the old-fashioned furniture, as, with a sort of pitiful tenderness, it is called. It might be, and very often, perhaps, as a rule, always was, clumsy and heavy; but it was sound. It had honest workmanship about it: indeed, in every, even the minutest detail of construction, the most scrupulous care was taken to give the very best work of which the workman was capable. He then thought of something more than profit; principle was not overlooked. So that of the workman of old it could be said, with almost universal truth, that he was a "workman which needed not to be ashamed."

ORNAMENTAL WORK IN MOULDINGS.

(BEING ONE OF THE SUB-SECTIONS OF "FORM AND COLOUR IN INDUSTRIAL DECORATION.")

CHAPTER III.

If the reader has attentively perused what, in the papers under the head of "The Ornamental Draughtsman," has been said on the art of drawing, and also in the early part of the paper entitled "The Building and Machine Draughtsman," he will have no difficulty in deciding which of these methods of obtaining the lines of mouldings, named at end of the preceding chapter, are in the domain of what is called "high art." The "contour" of a moulding is that view of it which is shown in what is technically called a cross or transverse section (see the papers under the head of "The Building and Machine Draughtsman"); or is looked at, in popular and graphic, if not strictly correct language, "end on." It is obvious that the exact form or outline of the curved parts, and their relation to and connexion with the subsidiary or joining parts composed of straight lines, can only be seen when the moulding is looked at in this direction. An examination of a moulding looked at in a point directly in front, or in "elevation," as the technical phrase is, would not give this precise information as to its formation. The term "profile" is also used to denote the outline or look of a moulding as looked at "end on" or sideways. This term is derived from two Latin words, *pro*, for, or *per*, by, and *filum*, a thread or line, and has come to be understood as a side view or elevation of an object; used only as a single word, it means the side view of a human face, or a portrait in side view. In fig. 2 (p. 82) the terms we have used above are illustrated—the part A in all the four diagrams being the cross or transverse section, the "end-on" view or elevation, the "contour" or the "profile"—and to indicate that it is shown as a "cross section" it is cross lined, or, technically described, "hatched," as in the fourth diagram. In all the diagrams in this figure (2) the parts marked B are what are called an "elevation" or "front view"—an end view being generally termed an "end elevation," a top or a bottom view, looked directly down upon or up at, a "plan."

"Profile," "Assemblage,"—Terms used in connection with the Technical Work of Mouldings.

It is right here, however, to state that the term "profile," although accurate enough as a distinctive appellation for the look presented by an end view or cross section of a single moulding, is most generally, if not most correctly, applied to a number of separate mouldings, which is usually designated as an "assemblage." Thus, in fig. 2 *a b c d* is a single or separate moulding, so also *g h* and *e f*; but at *i j k* there are two mouldings of different contour, and the whole as taken together are considered as an assemblage to which the term profile is applied. Seeing, however, that this term profile is so generally understood—we might almost say universally, certainly so in a popular sense—as the side view or "end-on" view of an object, it appears to us that it might save mistake on the part of some if the word "assemblage" were alone used to designate an arrangement of several distinct mouldings in the mass or block.

General View of the Points connected with Mouldings.—Technical Designations.—The Fillet.

A few of the general principles affecting the use of mouldings may here be stated, and this in connection with the distinctive features of each kind or variety. The diagram in fig. 3 illustrates the simplest form of moulding, which is made up purely of straight lines at right angles to each other, as at *a b*, *a c*. It is termed the "fillet," from the Latin *filum*, a thread or line, and this possibly because it is small and of fine dimensions compared with other and larger mouldings;

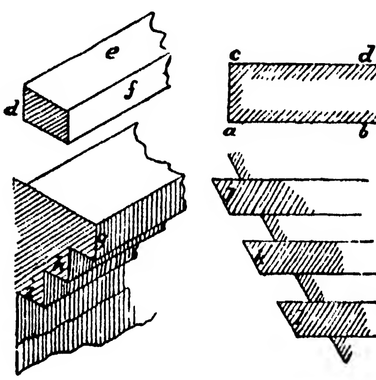


Fig. 3.

possibly, also, because its office is to connect or bind together the other mouldings which go to make up an assemblage; a thread in ordinary binding work being generally used for this. Be this as it may, such is the peculiarity of this moulding, the simplest of all, and such its office. Another name by which the "fillet" is known is the "cincture," from the Latin word *cinctura*, from *cingere*, to gird or bind, which means literally a girdle or belt to bind round an object—this meaning practically involving the same idea as the fillet, a part connecting or binding together other forms. The fillet is also known as the "annulet" (the more accurate spelling of which is "anulet") from the Latin *annulus*, the diminutive of *anus*, a ring. This obviously gives the idea of a circular body, "cinctured" or girded round, and is therefore much more applicable to the moulding next to be considered in order. The fillet is also sometimes called a "band," still more indicative of its office as a binding or bonding medium for other mouldings. It is also

called a "square," indicative of its right-angled and rectilineal surfaces.

The Bead.—The Astragal.

When the end of a fillet is not square, as at *d*, in section, or rectangular at faces, as at *e f*, fig. 3, but rounded in the way hereafter detailed in describing how the outlines of mouldings are obtained, as in fig. 4 at *a*, the moulding is termed an "astragal." This term is derived from a Greek word indicating in anatomy the heel bone below the ankle, and so applied to this moulding from its fancied resemblance to the swelling of the heel. The term "anulet," which we have seen is applied to the fillet in fig. 3, is, as we have said, much more applicable to the astragal in fig. 4; a section of a complete moulding of this kind being a circle or ring. The astragal is also, and perhaps most frequently, termed a "bead." And this is the most convenient term, inasmuch as that of astragal is apt to be confounded with a word sometimes used in joinery, which means a different thing. The term "bead" is a

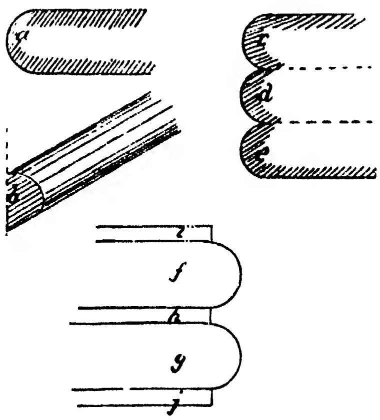


Fig. 4.

Saxon word indicating a small perforated ball, sphere, or globe of glass or metal, to be strung on a thread, an assemblage of the balls forming a necklace or other ornament. We find the "bead" moulding frequently curved so that its surface presents an appearance more or less distinct of a string of beads. Figs. 7, 9, and 10, Plate CCXIII., illustrate how the astragal or bead may be ornamented.

The "Torus" Moulding.

The moulding third in order to be named is illustrated in fig. 5, and is called the "torus," and is in fact but a bead of larger size than the "bead" used as such. There is also this distinction between the torus and the bead. The bead is always circular in section, as in fig. 4, or at *a* in fig. 5; whereas the torus is in the Grecian form of the moulding frequently elliptical in section, as at *b* and *c*. There are still two other distinctions between the torus and the bead: the torus, being the larger in section, is used in base mouldings, or where the greatest weight is to be supported; the bead, being smaller, in the upper part of structures; and while the torus is as a rule left plain on its surface, the bead is often carved or decorated with ornament—of which we have above given, and hereafter shall give further illustrations. The name "torus" is anglicised from the Latin *torus*, often translated as a "rope," but more accurately signifying the

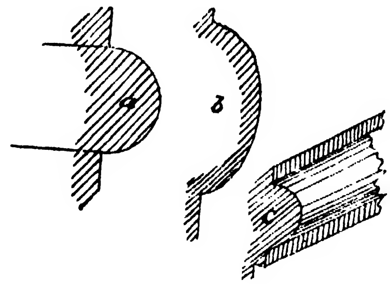


Fig. 5.

long tendrils of a vegetable or grass twisted together to form a rope; it also has other meanings, with which we are not at present concerned. Fig. 13, Plate CCXIII., illustrates how the torus may be ornamented.

The "Ovolo."

The fourth moulding in order is the "ovolo," illustrated in fig. 6; this word being derived from the Latin word *ovum*, an egg. And this not merely from the swell or curve of the moulding appearing like that of an egg, but also from the fact that this moulding is in the Ionic order generally, and in other instances, carved with an egg-shaped ornament which will be hereafter illustrated. The ovolo in section forms a quadrant or fourth part of a circle; hence is

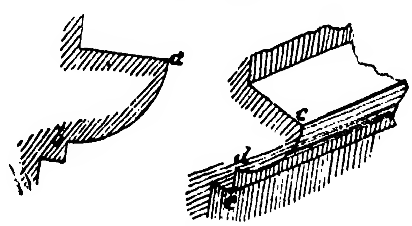


Fig. 6.

derived the other name, by which it is perhaps even more frequently called and better known—namely, the "quarter-round." It is also called the "echinus," we presume from some resemblance to the beautifully curved shell of the sea-fish known by that name. Fig. 1, Plate CCXVI., illustrates how the ovolo may be decorated; so also fig. 2 in same Plate; fig. 5, Plate CCLI., is in its contour modified from that in fig. 1, Plate CCXVI.

THE WORKMAN AS A TECHNICAL STUDENT.

How to Study, and What to Study.

CHAPTER XIII.

At the conclusion of last chapter we remarked that it was not an easy thing to separate the "how" from the "what to study," so mixed up with each other are the two departments. For it is of little avail to the student of technical literature to be told what are the branches he ought to study, unless he has quite made up his mind as to the way in which to, or the how he is to study them. If he has carefully read what we have in preceding paragraphs said under this head, he will have clearly perceived that, however good the books which he has obtained to aid him in his course of study, however competent his teachers may be, the ultimate result, which is the aim and object of his study to secure, the very reason of its existence, will depend upon himself. And unless he see this it may be safely concluded that anything which in the preceding chapter we may have said, or anything told him by his teachers, however earnest they may be in their efforts to secure his progress, may as well practically be unsaid. So true is this, that we have but little hope of any one who has to be argued into a belief that education is a good thing for him as practically furthering his progress in life. What experience we have had goes in proof of this; for we never knew one either defectively educated or totally so, who by mere persuasion only became so convinced of the loss he sustained by being so, that he gave himself earnestly to the making good his deficiencies. There are those who bewail, and with, we regret to say, but too good reason, the existence of that apathy on the subject of self-improvement which makes the number of those who avail themselves of the numerous facilities placed at their disposal to acquire technical knowledge to be easily reckoned by tens, when they ought to be reckoned by the hundreds, or even the thousands. And in bewailing this they confess to a difficulty to comprehend why this should be so, knowing as they do the raising or lifting power of education, and look around to trace the reason of it, and, failing to find it, lay the blame on all causes but the right one. If they only looked in the right direction they would not have far to seek. They would soon see that the true cause of so few availing themselves of the facilities they have for acquiring a technical education is not that those facilities are not numerous, or not easily available, but that the class for whom, if they be not specially designed, is that to whom they are specially useful, do not as a rule avail themselves of them. We do not here open up the question, which has been, and may yet be, much disputed, whether our facilities for giving technical education to young men are, or are not, well planned and efficiently carried out. Admitting their defects, or presuming that these exist, still it must be admitted that the systems most defective do contain a vast amount of good. But the point is, do the great majority of those to whom technical education is beneficial avail themselves readily, of their own free will, of what is actually within their reach? There can be but one answer to the question, however painful may be the thoughts to which it gives rise. Those who have had, or now have, much to do with technical education know but too well that the instances are but comparatively few of those who are so determined to get education that, rather than not have it, they are prepared to make great sacrifices and devote earnest and anxious endeavours to it.

An Ardent Desire for Knowledge required by the Workman as the First Step in its Acquisition.

Let the number of those who do attend our technical classes be polled, and after deducting from the gross number those who are not daily engaged in the hard actual labour of technical industries, the number remaining of those who do will be found to be so very small, as to raise disheartening thoughts even in the minds of those who are most sanguine as to the spread of practical knowledge. We might learn much that is of practical common-sense use from the plain old proverb, "You may take a horse to the water, but you cannot make him drink"; nay, you may even do more, and take the water to the horse with the same negative result. Unless the animal has a thirst for water, it is in vain to expect that he will take it, all your efforts and wishes that he would do so notwithstanding.

So with the young man. He may have all facilities offered him by which he may, as the saying is, "better himself in life" by becoming well educated, and this with a precise and definite reference to his special trade or business, yet, unless he possesses in himself a true and an ardent or "burning thirst" for this knowledge, he will practically let these facilities pass unheeded by. And even if he does seemingly avail himself of them, he may, without this thirst for knowledge, be in truth only apparently acquiring. As a man with a burning thirst spares no effort to obtain what water may be within his reach, and will think no toil ill repaid if he succeeds in getting it, so a man with a desire for knowledge thinks no effort too great, no sacrifice of ease or the giving up of so-called pleasure worthless, to gain that which he feels to be his eventual life. Our self-made men, who in various branches of our industrial work have made themselves famous, and who gave to their work the supremacy which has made their country no less so, in the his-

tory of industry, acquired *their* knowledge under the very greatest of difficulties, and acquired it, moreover, by a strain on their mind, and by a voluntary deprivation of much that constitutes what is called ease to the body, of which we fear but too many amongst our rising generation have only a feeble conception. The facilities which even the poor amongst our technical workers have for education did not, in the times when these self-made men flourished, exist. It was only the rich and the well-to-do who could obtain help in technical or special education, and even they had to create, as it were, special facilities to meet their wishes, as few publicly organised means then existed.

Method in Study Absolutely Essential to secure Success in Acquiring Knowledge—Books alone will be of Little Benefit without it.—Self-Instruction, or Home Study.

We have said enough, but not more than enough, on the subject of the spirit of self-determination in which the technical workman must set about his education; and from this, as well as from the prominence we have given in preceding paragraphs to certain points of mental discipline, he will perceive that we are inclined to place greater importance upon the method of his study than even upon the subjects of it. In saying this we do not ignore the importance of having a well-devised system of study, for system in itself includes—if it be not itself—order; and of the advantages of "order" to the pupil we have said already somewhat. Nor, in placing, as we here do, such an importance on the method, do we lose sight of the object of study. All that we wish to insist upon here is, that if he gets laid down for him a system of study, he is not to suppose that knowledge forthwith will follow. Some may be inclined to think that no one could be so stupid as to think thus. We are not quite so sure of this. Those who have had much to do with youth, and perhaps more especially with those who are connected with the arts of construction and design, have come across youths who were vastly more eager to become possessed of a fine set of tools and instruments than to give the time, the patience, and the enthusiasm necessary to enable them to do really good and useful work with them. The best and cleverest architectural and engineering draughtsmen are not always those who possess the finest and most expensive "set" or "case" of instruments. We should not, of course, ignore the value nor despise the utility of the finest instruments and appliances as aids to the execution of good and quickly done work, any more than we ignore the value of good text-books for the pupil in technical knowledge. But we should like to see a youth do the best work he could with the modest tools which befit beginners, and possessed of an eager desire to do better, before he displayed an equal eagerness merely to have the fine or the finest tools and "nothing more."

In offering our remarks on the subjects making up a distinct or specific system of study, the reader will understand that these will refer more especially to the case of pupils who, if not wholly, at least mainly, will be self-taught. In the case of those attending classes, they will have, of course, a regular course laid down for them to follow, and a series of text-books in relation thereto. And, as a rule, it will be found that, if each teacher has not his own system of study, he at least has his own favourite text-books for it. Much, however, of what we shall now give, although designed for, at least more particularly applicable to, the self-taught pupil, will be applicable also to the pupils who are engaged in studying in regularly organised classes.

Class of Books or Subjects to Study.—Considerations affecting this.—Branches of Education Common to all Varieties of Study.—Important Bearing of them to the Technical Workman as a Student.

It would seem scarcely necessary to say that the subjects forming the system of study should have as close a bearing as possible upon the practical daily work of the pupil, or what he may design to be his work. But although this may be so, it is essential to be borne in mind nevertheless, for, obvious as it appears to be, it conveys a fact which is but too frequently overlooked. To obtain one advantage this plan possesses is so important that it would be worth while for our pupil-student to follow it, even although it had no direct bearing upon his practice in future work. This advantage is that it prevents desultory study; it keeps the pupil to one line of study, and from that wandering, so to call it, to and fro amongst books and objects of study which, like other roaming, has its own delightful attractions; man being, as some one has defined him to be, a wandering or vagabond animal. Be this as it may, this unsettled system or rather style—for it has no claims to be considered a system—of study is almost always certain to induce a careless habit, as prompting him who indulges in it to leave a subject upon which he has been some time engaged, to take up with some other which appears to him to be "more useful." It is by this phrase that he deceives himself into the belief that he is wise to make the change from its utility, whereas, in reality, he is but merely charmed with the view of its novelty. Study entered upon and carried out in this spirit is not deserving of the name; it is mere trifling, and, like all trifling, will only end in disappointment and loss. The course of study which is arranged to bear the most closely upon the object or work in life will, in proportion to the ernestness with which it is pursued, not only have a practical value as advancing the interests of his life work, but it will be the best means of enabling the student to avoid and to secure immunity from the dangers of the desultory study we have censured.

THE ROAD MAKER.

HIS WORK IN THE LAYING OUT OF ROADS IN RURAL, SUBURBAN AND TOWN DISTRICTS, THEIR CONSTRUCTION, REPAIR, AND IN THE CHOICE AND USE OF THE VARIOUS MATERIALS EMPLOYED.

CHAPTER XI.

Excavation and Embankment of Roads.—Calculations.

"GIVEN the breadth of the balance-line of a road cutting in sidelong or sloping ground, the perpendicular depth at the centre-line in any cross-section, the angle of inclination of the ground and that of the slope of the cutting, to find the distance on the surface at which the slopes in such section will run out at either side of the centre-line."—To the product of the natural cosine of the angle of inclination of the slope of the higher side of the cutting, multiplied by twice the depth of the cutting at the centre-line, add the product of the natural sine of the angle of the slope of the higher side of the cutting multiplied by the breadth of the balance-line; then divide that sum by twice the natural sine of the difference of the angle of inclination of the slope of the higher side of the cutting, and that of the side fall of the surface, and the quotient will be the distance from the centre-line at which the slope of the higher side of the cutting will run out at the surface of the ground. Then, to the product of the natural cosine of the angle of inclination of the slope of the lower side of the cutting, multiplied by twice the depth of the cutting at the centre-line, add the product of the natural sine of the angle of the slope of the lower side of the cutting multiplied by the breadth of the balance-line; then divide that sum by twice the natural sine of the sum of the angle of the inclination of the slope of the lower side of the cutting, and that of the side fall of the surface, and the quotient will be the distance from the centre-line at which the slope of the lower side of the cutting will run out at the surface of the ground.

Earthworks in Road Making (*continued*).

Resuming the calculations required in the construction of roads where cuttings and embankments are necessitated by the varying contour of the land over which it traverses, we give a rule "to find the area of the trapezium or figure of a cross-section of a cutting."—Take from a correct drawing of the section the length of a diagonal from the point where the slope of the upper side of the cutting runs out to surface to the angle included by the balance-line and the toe of the slope of the lower side of the cutting, and the lengths of the perpendicular distances from the toe of the slope of the higher side of the cross section of the cutting to the diagonal, and from the point where the lower side runs out to the surface to the diagonal; then multiply the length of the diagonal by half the sum of the perpendiculars, and the product will be the area of the section.

Example.—Required the area of a trapezium of which the diagonal is 63, and the perpendicular distances from the opposite angles to the diagonal are 12 and 4.

The sum of 12 and 4 is 16, the half of which is 8. The product of 63, the length of the diagonal, when multiplied by 8, half the sum of the perpendicular, is 504, the area of the trapezium required.

"To find the solid content of a cutting from the areas of the trapezia of the several cross-sections, and the distances between them."—The process of calculation is the same as in the last case; the rule and example need not, therefore, be repeated.

The third case, previously alluded to, in which earthwork may be required in the construction of roads, is when the road is made along the side of a steep hill, and in which the sections of the excavation will be triangles. In this case the whole breadth of the road may be included in the excavation, or it may be partly in excavation and partly in embankment, as shown in the diagrams, figs. 3 and 4, Plate CLXVIII.

Making the breadth of a road partly in excavation and partly in embankment is very expensive, and should never be had recourse to except under circumstances of the greatest necessity.

When, however, a portion of the breadth of a road cannot be avoided being made in embankment, the lower part of the surface of the slope of the hill side should be benched out into steps at right angles to the natural surface, and the material carefully put into the steps in thin strata and well pinned or rammed as the work proceeds; as without such precaution, on steep hill sides, the embankment will be certain to slip unless supported by a retaining wall of great strength. By benching out the surface of slope in the way described, and the material being laid inclining from the slope, a retaining wall may be dispensed with, or, if required, it may be very much lighter than when such precautions have not been taken.

"To find the distance from the side of a road at the lower level of the slope of the side of a hill at which the cutting will run out at the surface, the breadth of the road and the angles of inclination of the slope of the surface of the side of the hill and that of the cutting being given."—Multiply the breadth of the road by the natural cosine of the angle of the inclination of the slope of the cutting; then divide the product by the natural sine of the difference of the angle of the inclination of the slope of the cutting, and that of the slope of the natural surface of the side of the hill, and the quotient will be the distance required.

When the breadth of a road is partly in cutting, and partly in embankment, to find the distance, at either side of a road, at which the slopes of a cutting and the embankment will run out at the surface—the breadth of the road in which it is in cutting or embankment, the angles of the inclination of the slopes of the cutting and embankment, and of the slope of the side of the hill being given.

For the cutting, multiply the breadth of the road which is in cutting by the natural cosine of the angle of the inclination of the cutting; then divide the product by the natural sine of the difference of the angle of the inclination of the slope of the cutting and that of the slope of the natural surface of the side of the hill, and the quotient will be the distance at which the slope of the cutting will run out at the surface.

Earthwork of Roads *(continued).*

For the embankment, multiply the breadth of the road which is in embankment by the cosine of the angle of inclination of the slope of the embankment; then divide the product by the sine of the difference of the angle of the inclination of the slope of the cutting and that of the slope of the natural surface of the side of the hill, and the quotient will be the distance at which the slope of the embankment will meet that of the surface of the side of the hill.

When the angle of the inclination of the slope of the cutting and that of the slope of the embankment are equal—which will generally be the case—the triangle representing the cross-section of the cutting and that representing the cross-section of the embankment will be similar; and the distance at which the slope of an embankment will meet the slope of the surface will be the quotient of the product of the distance at which the slope of the cutting will run out at the surface multiplied by the breadth of the embankment being divided by that of the cutting.

To find the perpendicular depth or height of a cutting or embankment, multiply the result of either of the two last rules, which a particular case may require, by the natural sine of the angle of the inclination of the slope of the natural surface of the hill, and the product will be the depth or height required.

To find the area of a section of a cutting or embankment, multiply the distance at which a cutting will run out to the surface, or at which the slope of an embankment will meet the surface of the slope of the side of a hill, by the perpendicular depth or height, and half the product will be the area required.

To find the solid content of a cutting or embankment for a road, the same rule applies as that given for the other two former cases, and need not be repeated.

It may frequently happen that earthwork may be required to be measured, and the quantity calculated after the work has been executed, when access cannot be had to the sections; in which case the following mode of obtaining the dimensions, and from them the quantities, may be adopted:—Take the angle of inclination of the slopes by a clinometer, and measure the length of the slopes and the breadth of the balance-line, from which elements the following calculations should be made—The perpendicular depth of the slope will be found by multiplying the length of the slope by the natural sine of the angle of its inclination; and the talus or base of the slope will be found by multiplying the length of the slope by the natural cosine of the angle of its inclination.

The most usual manner of expressing the slopes of embankments and cuttings is by the proportion subsisting between the base and perpendicular height; but if the angle of the inclination be required, then—

To find the angle of inclination of a slope from the proportion between its base and perpendicular height, divide the number representing the proportion of the perpendicular height by the square root of the sum of the squares of the numbers representing the proportion between the base and perpendicular height, and the quotient is the natural sine of the angle of inclination.

To find the areas of cross-sections, multiply the bottom of the cutting by the sum of the perpendicular heights of the slopes at each side of the section; then multiply the perpendicular height of one slope by the base of the other, both alternately, and half the sum of the three products will be the area of the cross section.

The Mechanical Condition of Road Surfaces as affecting the Traction of Vehicles running on them.

We now come to consider the effect of the mechanical condition—in other words, the state of repair in which the road surface is—upon the tractive force exerted by animals pulling or dragging heavy loads over its surface. It will be obvious, on very slight consideration, that the surface of a road may be such in its perfect construction that the tractive force required to pull or drag a heavily loaded carriage, cart, or waggon over and along it may be the minimum force required; while on the other hand this may be the maximum when the condition of the surface of the road is so bad that, constructively considered, it could not be worse. Between those two extremes of the best and the worst there will be a wide variety of points, at each of which the tractive force required will be in proportion favourable or otherwise, just as the point approaches the best or the worst condition in which the surface of the road may be.

THE LAND DRAINER.

DRAINAGE OF LANDS OR SOILS SUITABLE FOR THE CROPS AND LIVE STOCK OF THE FARMER.—ITS HISTORY PRINCIPLES, AND PRACTICE.

CHAPTER VIII.

On ground having a considerable declivity, or the declivity having several gradients, or even in large fields requiring great and continuous length of collecting drains, it will be proper in the first and last cases mentioned (on p. 90), to have one or more submains across the direction of the collecting drains, with such obliquity of direction across the declivity of the surface as to afford fall for a tolerably rapid current of water; and in the second case there should be a sub-main at the bottom of each gradient. The submains referred to are required to prevent the wash likely to occur in heavy summer showers after long-continued drought on clay soils, or to relieve the small drains, and prevent them being blown, or being overcharged from any cause whatever.

Materials used in the Construction of Drains.

We now come to the consideration of the materials by which the drains of various forms can be constructed, in which the following remarks are to be considered as chiefly introductory and partly supplementary to what has been already given. The further details will hereafter be considered; meanwhile we now more immediately concern ourselves with some important details respecting the form to be given to ducts or channels of various kinds in which water is conveyed from one point to another.

As regards the materials of which the drains are constructed, until after the commencement of the present century, in the rare instances compared with the present time in which draining operations were undertaken, the ducts of main drains were usually conduits formed of dry and rough masonry, and those of the collecting drains consisted of the trenches for the same, being partially filled with stones, the branches and sprays or twigs of trees covered with turfs, and in bogs and lands of peaty soil sometimes even with dried peat; but at an early period of the present century, about 1811, tiles came into use for forming the ducts of drains. In the early period of the use of tiles as a material for the ducts of drains, they were simply slabs of clay made by hand, and bent over a mandril into the form of a horseshoe or inverted U, sometimes, though not always, to be placed in the drains upon flat soles of the same material or slate, to prevent their disarrangement from the bottoms of the drains being washed out by the current of the water therein. This appears to have been the best kind of duct for covered drains until the invention of tile-making machines, the first of which was by the Marquis of Tweeddale in 1836; but it was not until 1839 that the machine in question was perfected, and came into much use. This machine was of a somewhat complicated construction, and adapted only for making the horseshoe tiles then in use. This was followed in a few years afterwards, about 1843, by the invention of other machines of more simple construction, by which pipes of tile for the ducts of covered drains could be made with great accuracy, despatch, and economy; and which have now superseded every other material and form for the purpose, wherever clay for the manufacture and fuel for the burning can be had at a reasonable cost. From facilities of transport by railway in every direction throughout the United Kingdom, it will be but in very few localities in which cost will be a preventive to the use of tile pipes for the ducts of covered drains, even where neither suitable earth nor fuel is to be obtained in the neighbourhood. Such being the case, future remarks on the material for the ducts of covered drains will be confined to pipes of tile.

Tiles that have not been thoroughly air-dried previously to being fired—those made from clay having too large a mixture of sand, or having nodules of limestone or chalk in it, and those that have been made during frosty weather—should always be rejected as being liable to spontaneous breaking in the drains. Tiles of good quality are heavy, and emit a ringing sound when struck; but they should not be so hard burnt as to be vitrified. The quality of drain tiles should be that of the best garden pots; and the best mode of testing their quality is to steep a sample pipe for three or four hours in water, and then to place it before a hot fire, and should it remain hard and whole after such an ordeal it may be safely used.

Common clay tile is undoubtedly the best material for the ducts of covered drains, and, for the same reasons already given, for the sides and bottom of an open watercourse, are tangents to a semicircle the radius of which being the depth of water therein, the best form for such ducts is a plain hollow cylinder. Supposing the greatest depth of water in such duct to be its radius, or half full, its hydraulic depth for calculating the velocity in it will be one-fourth the diameter or half the radius of the bore of the pipe. Cylindrical pipes of tile are made by machines in great perfection; and, when fuel can be had at a reasonable price, they may be produced at a very low rate.

Drain pipes are made by manufacturers of from one to nine inches diameter of bore, and they may be obtained of still larger size when required. The usual and, indeed, the most convenient length of tile pipes is twelve inches.

Special Remarks on Drainage.—Experiments in Different Systems of Drainage.

Having given remarks upon and rules connected with the form or shape of drain ducts, it may be suggestive of some thought to refer here to what has been done, and what very likely may yet be done in connection with experiments in different systems of draining and the various modifications in what may be called the original or established plan of land drainage. For although of late there has not been much lively discussion on the subject of drainage, it does not follow that all the points which were at one time disputed as connected with the various modifications of the system are so finally settled and agreed upon as to give no occasion for any difference of opinion. For it so happens, as in almost every other branch of social and scientific economy, that discussions take place in what may be called cycles. Subjects are, therefore, brought forward by certain circumstances into such prominence that their discussion is carried on so energetically, and with such fulness, that neither time nor space seems left for the consideration of other points, and it seems as if this were but the one topic which required discussion. Those who are intimate with the past history of agriculture in this country will easily draw to recollection numerous examples of this peculiarity in social and scientific matters. And drainage has been no exception to the law, if law it may be called. At the same time it is to be observed that the question of drainage is in a much more settled condition now than it was years ago. We do not hear so much of the faults and deficiencies of what we have called the established system, nor are so many modifications of it proposed. And of those proposed years ago, some seem to have died out, or have only been kept up by a very few—sometimes only been confined to the practice of the original introducer. There seems, therefore, to be what may be called a general or universal consensus of opinion in favour of the tubular deep or thorough draining system we have described as being the best.

It would be wrong, however, to conclude that, because this is so, therefore there will be no improvement made in its practice or modifications in its principle. It may yet be that some one will come forward to propose and carry out, and that successfully, some system which, if it be not quite as complete a revolution of the present as that was on the old, may yet present such very striking points as to entitle it to be called a new method of draining land from an excess of water. We do not say that there is any great probability that this will happen: all we desire to remind the young agriculturist or land drainer is that it is very unsafe for any one to conclude that because a system appears to be perfect it is not likely to be improved on or even altogether to be superseded. There is, literally, no standing still in practical science: its motto may be said to be "farther and forward,"—and thus we find that the model system of to-day no longer exists in its integrity to-morrow, and by the next "the place which knew it will know it no more for ever," it being wholly superseded by some method totally new and altogether different alike in principle and detail. Nor must the youthful reader suppose that because some branch of science may remain, as it were, dormant, and for so long a period that it appears to be incapable of being applied to any strikingly extensive and practical use, that it will always remain so. Such seems to have to go through this period of dormant inactivity till the time and the man come at which and by whom it is wakened up, so to say, to a new and startling vitality. We have many examples of this, but we need only mention one, and that the most striking of modern times—electricity.

But although this may not apply to the subject of our paper, it is futile to conclude that it will never do so. Certain, at all events, it is that, settled as all points of drainage would from circumstances appear to be, there are many points very far from being decided, in regard, if not to its inherent principles, certainly as to its details. There are many puzzling points in the practice of drainage in certain soils and districts which have not yet been definitely settled, and when met with in practice have simply been made the best of—although that has been far from being the best—and set aside for final settlement to some convenient day, should that ever come about. All such points have to be settled by experiment; and that many experiments have been made during past years, and are being made now, we have no doubt of. The cycle of discussion will come about in due course, and we shall hear all and very likely much about them. The young man about to enter into practice will, if that be in any way extensive, have abundant opportunities to convince him of the necessity of numerous experiments; and in conducting them the following remarks, being those we have in the beginning of the chapter alluded to, will be found useful and suggestive.

With reference to this important department of experimenting, the editor of the *Mark Lane Express* has made some most suggestive remarks. In insisting upon the necessity of attending to two points generally lost sight of in agricultural experiments—the manner of conducting them, and the manner of describing their results—he directs attention to the anomalous position occupied by agricultural nomenclature, comparing the confusion connected with it to that of Babel, where different terms were used to denominate the same thing—one calling that a brick which another termed mortar.

THE GRAZIER AND CATTLE BREEDER AND FEEDER.

THE TECHNICAL POINTS CONNECTED WITH THE VARIETIES OR BREEDS OF CATTLE—THEIR BREEDING, REARING, FEEDING, AND GENERAL MANAGEMENT FOR THE PRODUCTION OF BUTCHERS' MEAT AND OF DAIRY PRODUCE.

CHAPTER XXIII.

RETURNING to the subject of cattle breeding, referred to in the last paragraph of preceding chapter, we have to remark that while the experience afforded by the practice of those who have systematically adopted the permanent stall feeding—the "*système permanente stabulation*" of the French and Belgian agriculturists—gives abundant proof that the produce of dairy cows is greater, and the fattening of cattle quicker, than under the ordinary system in such favour with us. Hence it is that, looking at what has been done—is over enormous districts being daily done—under the system of permanent or continuous stall feeding, not a few of our most advanced farmers begin to think this: that *if* the new phase of British farming, in which wheat or corn cultivation will give place universally to cattle breeding and rearing, and the production of dairy produce, as milk, butter, and cheese, is to be really successful, it can only be made so by the adoption of the stall feeding system, so far, at least, as our dairy stock is concerned; and in the case of our fattening stock, its adoption to be secured for at least one-half, if not three-fourths, of the year. And when this, which we are inclined to believe is the true position of the proposed great change in the characteristics of British farming, is realised, if ever it be so, this will be the result. Not, as some would-be authorities on farming and keen and not over-kind critics of British farmers aver with such persistency, that grass lands will take the place of arable culture—which is, according to them, of necessity to disappear wholly—but, on the contrary, that arable culture will be enormously increased, and that it will, in place of being devoted to cereal or corn crops, as at present, be given to the production of the wide variety of feeding crops demanded by the permanent stall-feeding system. And a further, or rather a necessary result, will be that, in place of grass lands being the rule, they will, wherever this system is adopted, be the exception, and this for the reasons elsewhere in this paper or in that of "The Farmer" given. And these results will be somewhat different to those anticipated by the writers and critics above alluded to, their deductions having been derived from an actual ignorance of what are the practical circumstances of British farming. The very phrase which constitutes the text of their predictions in itself betrays their ignorance of those circumstances; for, however much the increased attention to cattle fattening and to dairy produce may demand grass land, they never would or could do away with arable culture, which, even under our present system of feeding is absolutely essential for the production of the foods which that system demands. Arable culture is not synonymous with corn culture, as the writers and critics we have alluded to seem to think.

The Soiling System specially adapted for Small Farms.

Whether we shall yet have the system of permanent stall feeding applied to large farms much more extensively than it has yet been applied, time will show. Although sound practice points in this direction, it is beyond any doubt that the system is peculiarly well adapted to the circumstances of small farms. When this is carried out with judgment and accuracy of detail, a greater number of cows, for example—and it is with dairying that small farmers will chiefly concern themselves—can be kept with than without it, or, what is the same thing, the same number can be kept on a less extent of land than under the old method. The system, no doubt, demands an extra amount of labour on the part of the farmer; and this is perhaps the reason why it has not been adopted to any great extent with us, where labour of all kinds is so expensive, and is daily becoming more so. But that the labour thus involved is well repaid by the extra economy of the system, all experience goes to prove. The extra labour which the system involves arises from its two leading principles; the first of which is "the cropping of the land for the materials for feeding." The food obtained from pastures forms no part of the system properly carried out; these—with the exception in some cases, but not in all, of a small paddock or paddocks being reserved for exercise ground, or for calves—are entirely dispensed with; and the food required by the stock is raised specially on land devoted to this purpose. One feature of the system of cropping adopted is the raising of a great variety of produce, and on a plan of rotation so arranged that this produce is obtained in succession. The land is cleared of one crop or variety of produce, and is immediately prepared for the reception of another. But the crops are generally divided so that one set is adapted to give a succession of cuttings of green food, the crop remaining on the ground to yield the number of cuttings for which it is adapted. The other division of the crops comprises those crops which, after yielding their first produce, are removed from the land to give place to a different class. The land is thus kept in a state of perpetual production, and from the necessary frequent workings to which under this system it is subjected, and the repeated applications of manure according to the crops reared, it is maintained in a state of the highest fertility. This alone is an advantage of the system

worth giving some extra labour for. Being indeed the very aim and ultimate object of all arable culture, it would appear to be, as indeed it in reality is, pure folly for any one to consider it as a disadvantage of the system or of any system whatever. Where part of the crops raised are what are called forage crops, and these under the system adopted constitute their greatest proportion, the food is cut in its green state and carried to the house in which the cows or cattle are kept. This involves the second part of the extra labour of the system; and the labour is all the greater the more conscientiously the system is carried out,—for the food should be given as fresh as possible, and to insure this, small quantities only ought to be cut at a time, and this involves of course repetition of labour. One feature in the cropping of the land for the system is having, as already stated, a variety of produce, so that the advantages of a change of food will be obtained. On these advantages we have already remarked. This necessitates the laying out of the land in a series of comparatively narrow breadths.

Diversity of Views as to the Soiling System.

In connection with the question of "soiling" the cattle or cows in the house, there is, it is needless to say, a wide variety of opinions; and one of the main objections to it is its presumed or assumed unhealthiness. If, however, experience is to go for anything, that proves beyond a doubt that the rule is (where there are exceptions they but prove it) that where the buildings in which the animals are kept are constructed in accordance with sound principles, so that they shall be healthy; they (*i.e.* the animals) do not suffer from the system of soiling. We have referred to exceptions to this rule; but we believe that even of these a large proportion arises from the buildings in which they are housed being unhealthy, and experience would go far to show, if its results were faithfully and honestly recorded, that the system of soiling is more healthy than the system of out-field pasturing, as generally adopted. But it must be remembered that there are some circumstances more favourable to the system of soiling being carried out with economy and health to the cattle than others. Thus, for example, the soil, climate and locality of a farm will materially influence its success, inasmuch as they will obviously cause a difference in the facilities and consequent economy with which the crops may be raised necessary to carry out the system. This is a point too often lost sight of when the subject is being considered. Again, under some circumstances it may be more successfully carried out when applied to one class of stock than to another. Thus, it may pay better when applied to dairy cows than to fattening cattle, or *vice versâ*. The truth is, that, like all other systems, it must be carefully considered in all its relations to the circumstances of the farm, its soil, situation, etc., before it is adopted. But, if adopted, let its details be consistently carried out. The overlooking of this really common-sense principle lies at the root of a vast number of mistakes; in many departments of farming, mistakes which are laid to the credit or rather discredit of the system, while in reality they have no connection with it save that which is made by the carelessness of the experimenter. There is a great deal of truth in the old saying about "putting the saddle on the right horse," an operation by no means always done in the right way or at the right time, and sometimes not done at all in matters agricultural, where we should predicate with some safety that it would be done if done at all. One obvious point, necessary to be attended to under all circumstances, is that the cut food shall be supplied to the stock in small quantities at a time, so that it shall be fresh and sweet as possible. A second is, that the feeding appliances or methods of giving food to the animals be such that they will not be able to trample upon it and mix their *exuviæ* with it. Should these two points not be attended to, much of the success because much of the economy of the system depending on them will be sacrificed.

To supply the whole of the stock of the farm with food during the *winter months* requires the exercise of perhaps the highest degree of forethought and of skill on the part of the farmer. He must endeavour to proportion his crops in such a way that he will have an ample supply to carry him right through till spring; and yet not so as to find himself with a surplus, or, what is worse, a deficiency. Many farmers have lost themselves in this department, and have had to experience the chagrin of parting with promising cattle simply from lack of food to keep them on till spring. When this is seen on a farm, it may be fairly decided that a miscalculation has been made. It may be said that foods can be purchased to make up the deficiency of home-grown crops; but it must be borne in mind that the winter is the worst time to buy foods, as they generally at this period bring the highest prices; and to feed wholly upon such foods may and very likely will be such an expense that any likely balance of profit is lost, and it goes the wrong way, against the farmer. Further, purchased foods require to be given along with home-grown foods in order to get their highest results. So that, taking all those points into consideration, it will be seen how important it is that the farmer should be able to calculate what his whole stock will require of his own crops, and what of purchased foods, these latter being bought at the most favourable periods for effecting good bargains. And in this department also correct calculation must be made, so that the weights of materials bought shall not be over or under the mark.

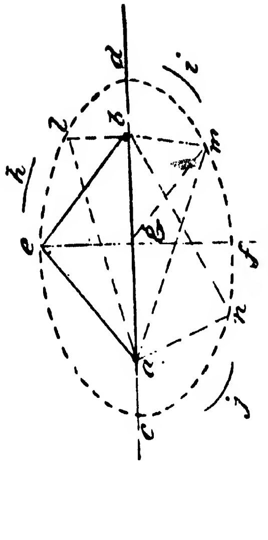
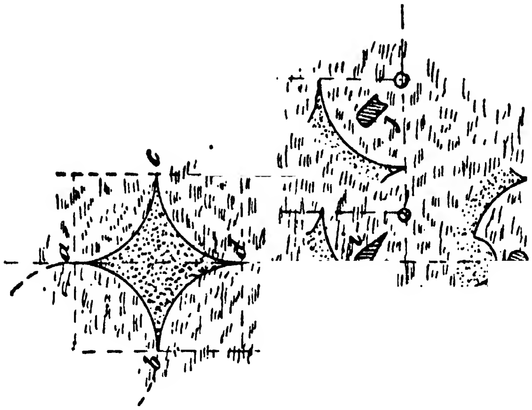


FIG. 3.



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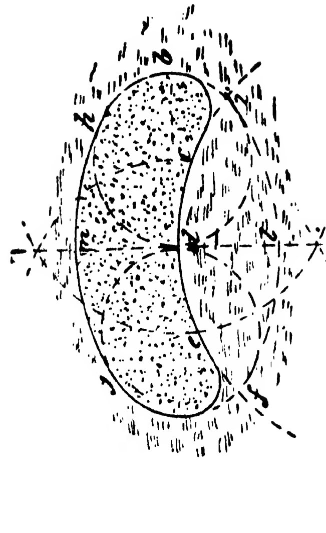

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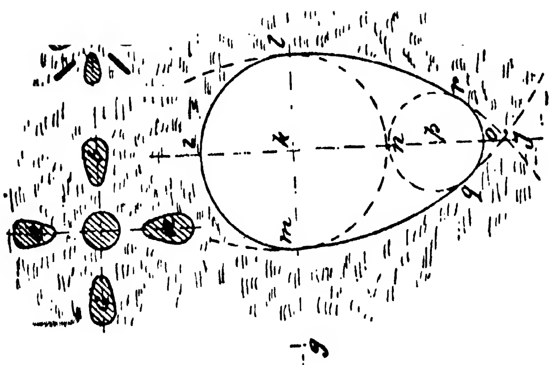


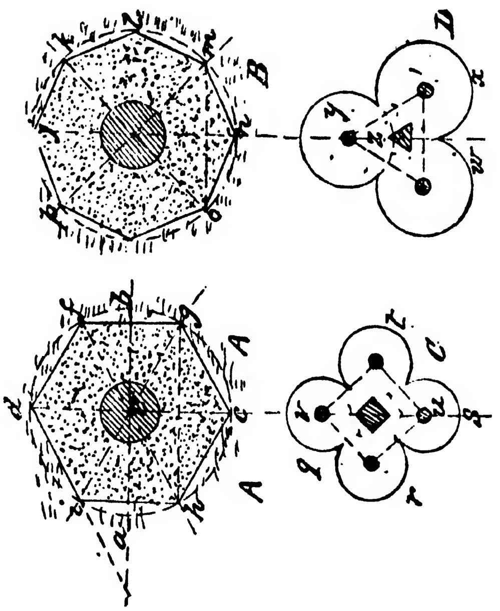
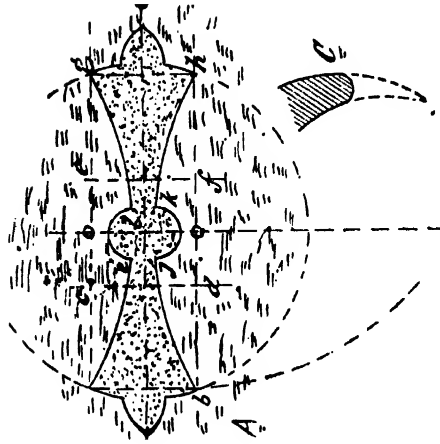
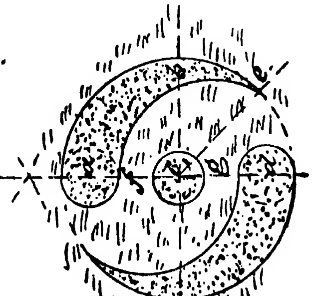
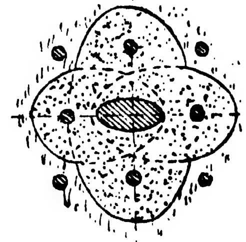


FIG. 5.







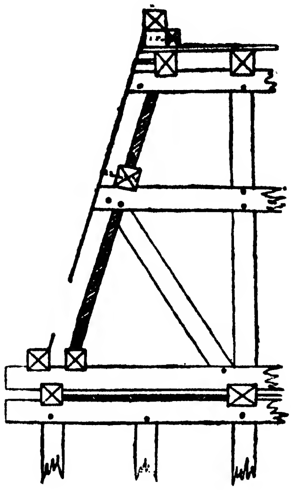


FIG. 1.

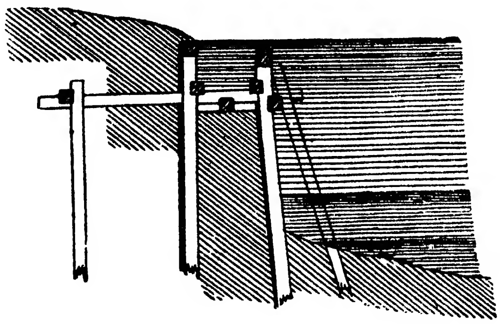


FIG. 2.

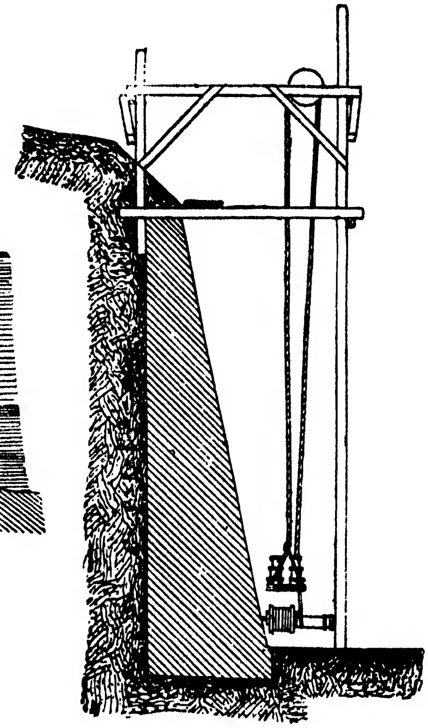
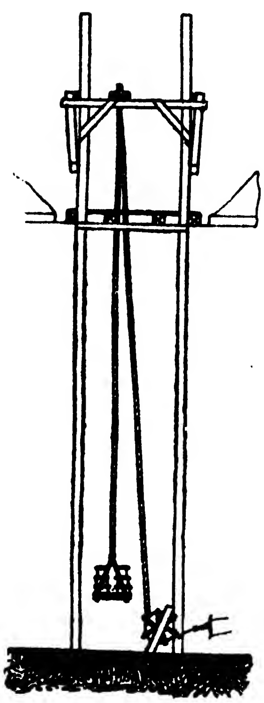


FIG. 3.



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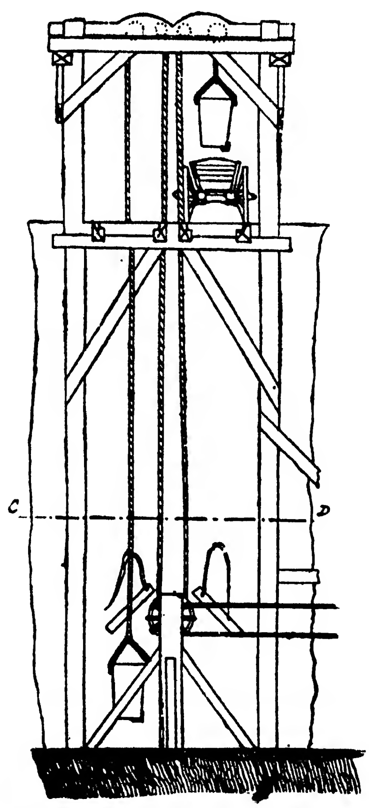

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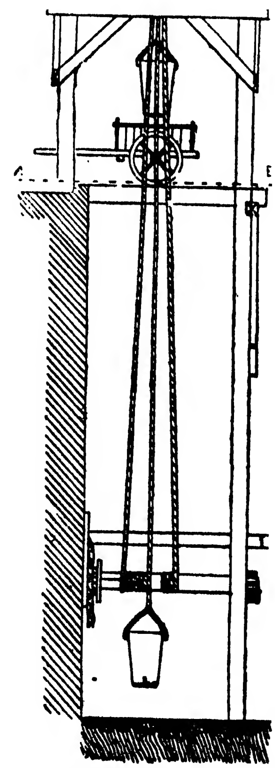


FIG. 6.

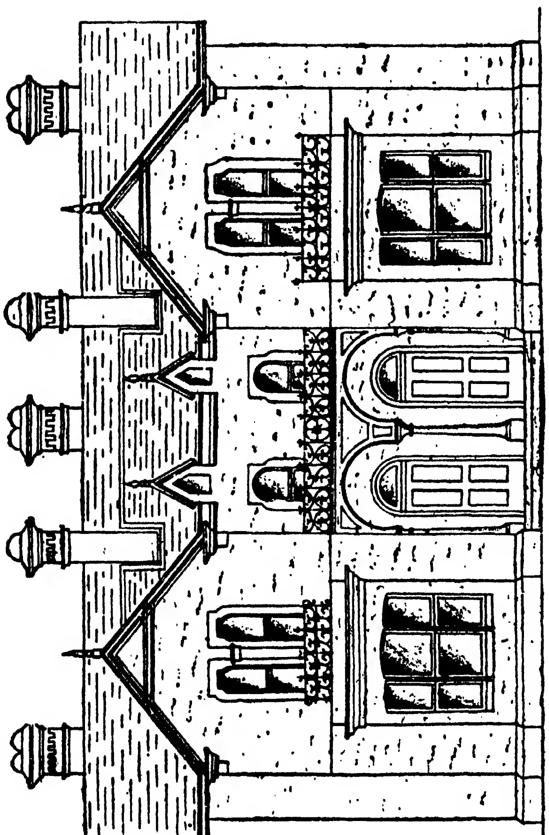


FIG. 1.

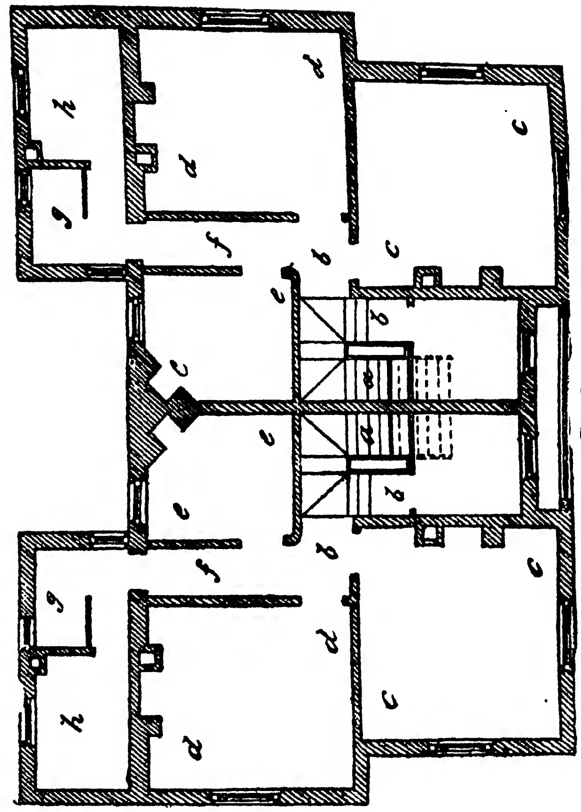


FIG. 3.

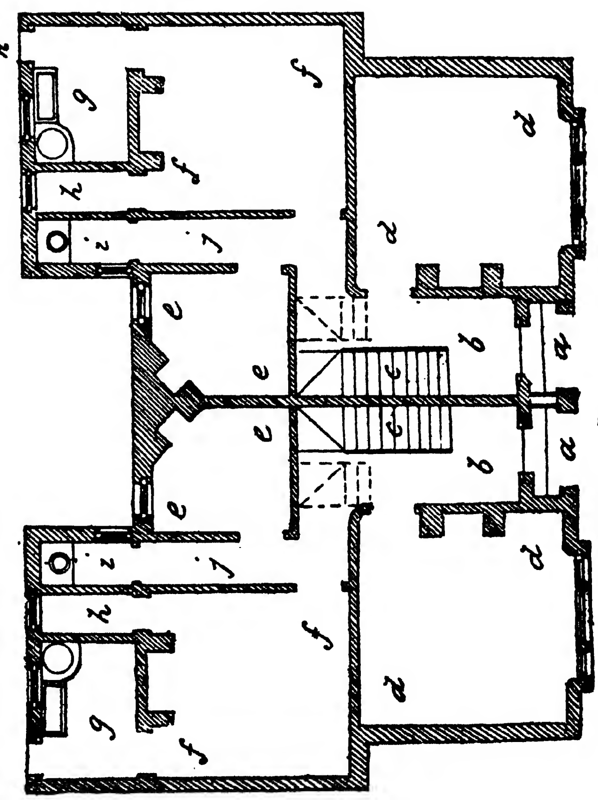


FIG. 2.

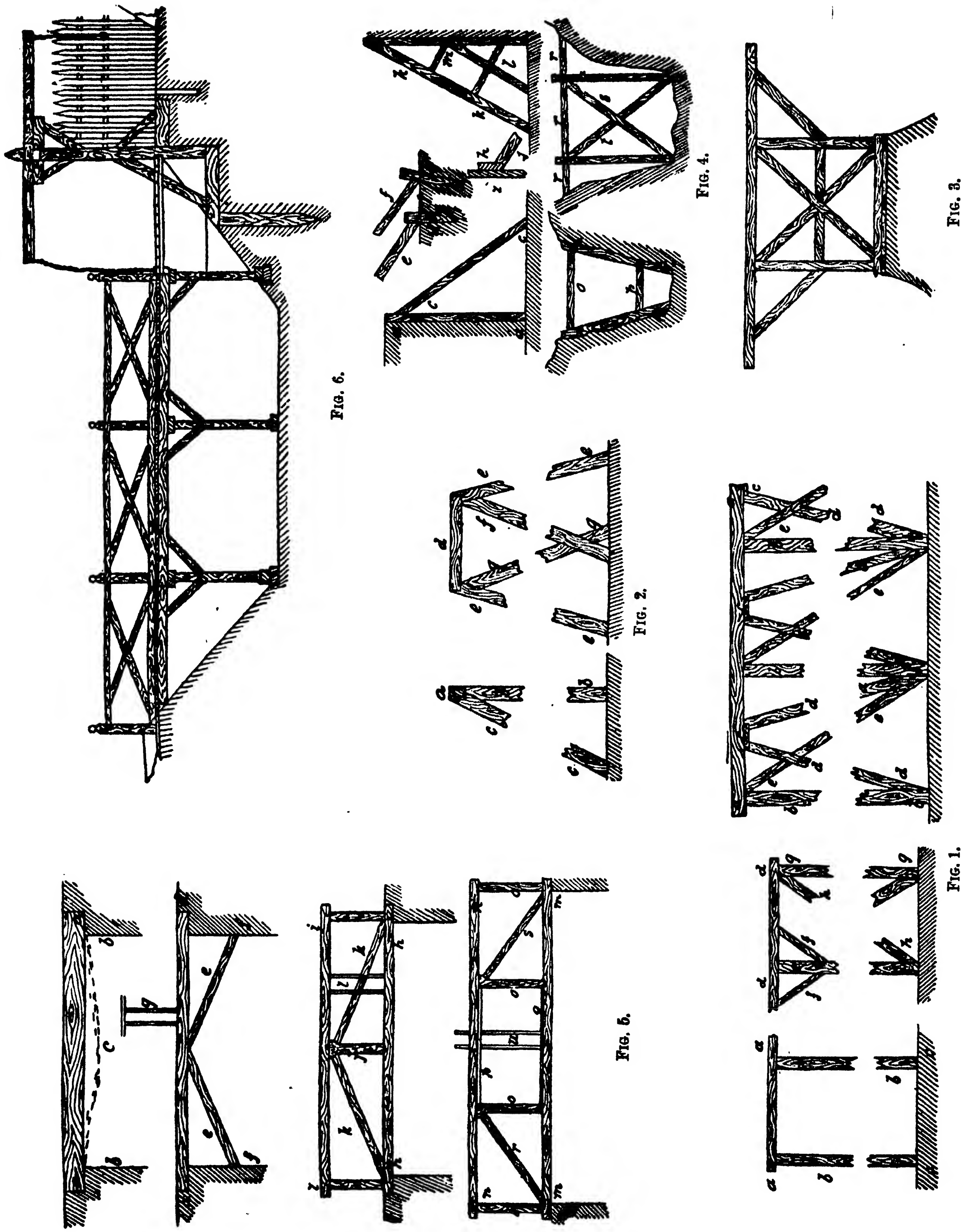


Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

THE TECHNICAL STUDENT'S INTRODUCTION TO THE GENERAL PRINCIPLES OF MECHANICS.

LAWS AFFECTING NATURAL PHENOMENA—MATTER AND MOTION.

CHAPTER XXXI.

Circular Movements induced by Motion of Fluids in Straight Directions (*continued*).

WE concluded our last chapter by introducing as an illustration the "undershot" water-wheel; and of this we proceed to give below a sketch in fig. 44. Here the boards *a, a, a,* corresponding to *a b* in diagram fig. 43, and which are technically termed "floats," are fixed vertically to the frame or shroud *b b*; and their movement due to the flowing water is transferred to the central shaft *c* by the arms. As the "floats" *a, a,* assume different angles in relation to the line of level of water, which is that of the direction of its force or pressure—and the consequence is that the water acts obliquely on them, as shown by the arrows at *f*, thus causing a certain loss of pressure or force of the flowing water due to its velocity, and which is only fully exerted when the water acts

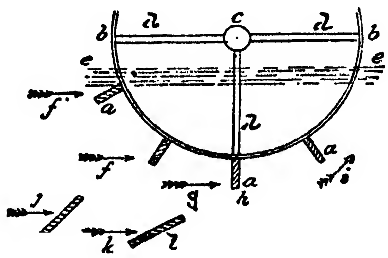


Fig. 44.

directly on the surface of the float to which it hangs vertically, as the floats rise towards side *i*, they have a tendency to lift the water up, thus causing another loss of power. In the paper "The Boat and Ship Builder" the principle of feathering the floats of a paddle-wheel will be found explained. The way this acts in the case of an undershot wheel is shown at *a a* in fig. 45, the water striking against the floats over the whole of their surface, and not obliquely, while they enter and leave the water at the line of least resistance. The velocity or force or pressure — we have seen that those are convertible terms—of running or flowing water, which, looked at from another point of view, is the fluid gravitating or falling from a high to a low level, is sometimes made to act upon a wheel placed horizontally —that is, the shaft or axis is vertical in place of horizontal, as in fig. 44. The water is led in such a way that it strikes the floats at one side of the wheel. If the floats radiate to the centre, as at *b* in fig. 45, the water strikes them obliquely. Better results are obtained in the working of such wheels when the floats are curved, as at *c, d,* and *e*. Those curved parts form practically a series of buckets, as they are inclosed between shrouds or plates, both at the under and upper sides of the wheel. It is upon the form of the *buckets*, or the inclined surfaces they present to the water impinging upon them, that the efficiency of a water-wheel really depends. A good water-wheel should give at least 75 per cent. of the power or force due to the velocity or pressure of the water; and if the effective power of the wheel falls below this, the form of the buckets or the curved surfaces on which the water impinges should be altered, until the best results are obtained.

Some Points connected with the Obtaining of Motive Power from a Flowing Stream.

There are some points connected with the method of obtaining power from a flowing stream, by the contrivance illustrated in figs. 44 and 45, which are of interest to the student of mechanics. The power obtained from the pressure due to the velocity of the stream going in the direction of the arrow *a*, fig. 42,

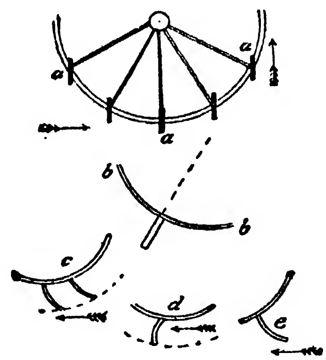


Fig. 45.

is in reality due to the resistance offered by the float *a* to the pressure tending to turn it in the direction of arrow *i*, for if there were no resisting power or surface at *h* there would be no communication of the pressure of the water at *a* to the central shaft *c* conveyed through the medium of the arm *d*. It follows that there must be a certain relation of the speed of the floats in the direction of arrow *i* to that of the velocity of the stream in the direction of the arrow *g*, and the student should here think out, in view of this relation, what would be the result if the float *h* ran away, so to say, from the stream at the same rate of speed as that possessed by the stream represented by the arrow *g*. The point here involved is of such mechanical importance, that it is essential that the student should have clear conceptions about it. He will remember our illustration, in a preceding paragraph, of the pilot or shunting engine pushing a train before it; and the relation of an engine which was going forward at precisely the same speed as the train in front of it gives an illustration of the

position of matters where the speed of a float is the same as the speed of the stream. To put the point in familiar language, the train in front would not, under the conditions we have just named, give time for the pushing force of the engine behind it to act, — just as a man could not give a blow to another man who was running in front of him at the same or a greater velocity. The practical deduction, then, in the case of deriving power from flowing water by the mechanical contrivance of the undershot wheel, as in fig. 44, is that the float *h* should have a velocity in the direction of the arrow *i* so much less than that of the stream represented by arrow *g*, as that time, so to say, will be given for the float *h* to receive the full effective pressure, or blow, of the water. In other words, the circumferential or circular velocity of the outer points of the wheel shall be in a certain proportion to the rectilineal flow or velocity of the stream. The proportion found to be best is when the velocity of the stream, as *g*, is two-thirds in excess of that of the float *h*; or the float *h*, or (what is the same thing) the velocity of the wheel at the

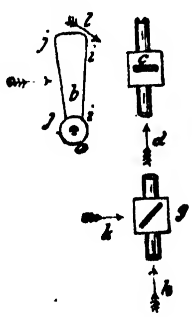


Fig. 46.

outer edge or circumference, is to be one-third of the velocity of the stream. The power of the wheel depends upon the ratio which the surface of the float *h* bears to the velocity or pressure of the water flowing in the direction of arrow *g*. The student might at first sight suppose that in calculating the power more than one float would have to be taken into account; but as the other floats are all placed more or less under oblique action, it is the rule in practice to describe them as effective factors in the calculation, for it will be seen on consideration that if there be in the water present between any two floats, as *j* and *k* in fig. 44, the water, while it presses the one, as *l*, forward, as by the arrow *k*, will, on the principle of action and reaction being always equal, press or force back the float *j* in the opposite direction, so that the forward or effective pressure will be *nil*, the two forces being balanced. There will, in some positions of the floats, other than that at *h*, be a slight excess of the forward over that of the backward pressure, but practically it is deemed best to consider only one of the floats—that in the position at *h*—as effective.

Oblique Action of a Fluid, as Air, on a Surface.—The Windmill.

A well-known exemplification of the power obtained by oblique action of a fluid on a surface is the "windmill." The principle of this source of motive power is exemplified in several mechanical appliances: we may illustrate it in *a*, fig. 46. In this let *a* represent a shaft or axle lying horizontally and capable of revolving in bearings. To this shaft suppose a flat arm or branch *b* secured. If this was so placed in relation to the shaft as to be at right angles to its line of length, as at *c*, the wind blowing in the direction of the arrow as at *d*, would simply tend to force the shaft end-on against its bearings, or break off the vertical arm, as *b b*. If this was placed as at *e*, coincident with the centre line of shaft, the wind blowing as at *f* would simply pass by the arm on either side, acting or pressing only on its thin edge. But if placed obliquely, as at *g*, with the edge nearest the direction in which the wind blows upon it, as at arrow *h*, the position would be as at *a b*, in which the edge of *b*

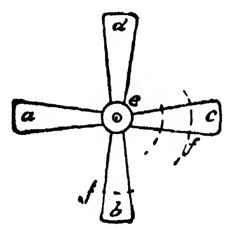


Fig. 47.

as that marked *j j*, would be nearer the wind, blowing as in direction of arrow *h*, than would the edge *i i*. The result of the impinging or striking of the wind in the direction of arrow *k* would be that in striking the surface of the arm *b* perpendicularly, a movement tending to bring forward the edge *i i*, or *g* in plan; but this being rigidly connected with the centre or shaft *a*, it would revolve under the pressure put upon the surface of the sail, and cause it to revolve, its upper or outer edge describing a circle, as at arrow *l*, round the centre of shaft *a*. This is the principle of the windmill. But to keep up the continuity of pressure thus communicated to the central shaft *a*, this is provided with four arms, as at *a*, *b*, *c*, *d*, fig. 47. These are set on a shaft *e*, and are kept always facing the wind, which we presume to be blowing in the direction of the arrow *a*, fig. 48. The arms are not hung vertically, but are, as shown in fig. 48, placed obliquely to the vertical axis of the mill building or conical tower, as at *b*, *c*. The oblique shaft *d*, which carries the arms *b*, *c*, has its step or bearing on the floor of the cap *i* of the tower or mill, and this carries

also the upper bearing of a vertical shaft *g*, which descends through the centre of the building and takes the power to the flour mill or other machinery situated in the lower apartment. This shaft *g* receives motion from the sail or arm shaft *d*, through bevel wheel gearing at *f*.

Mechanical Points connected with the Windmill,

As it is essential that the sails of the arms *b*, *c*, should always be kept facing the wind blowing as at arrow *a*, means have to be provided to shift or move round the arms *b*, *c* according as the direction of the

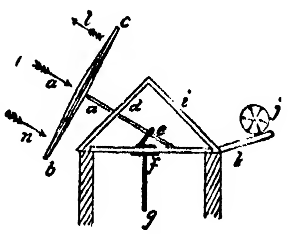


Fig. 48.

wind varies. In old-fashioned and small windmills a very direct and simple mechanism was adapted to this work, which may be yet seen in certain parts of this country, and more numerously on the Continent. The part or cap of the mill carrying the shafting, and in some small mills the whole structure, is supported on rollers, or works in a groove in the base, and a bent lever, as *a a*, fig. 49, secured to the mill structure *b*, is brought down and terminated near the surface of the ground at *b c*. In small mills mere bodily strength applied to end *c* of the lever *a a* brings or turns round the mill structure on its cap, so as to make the arms, as *b*, *c*, fig. 48, face the wind *a*. But in larger mills, or to provide for the extra power required in blowy weather for turning the shafting, small capstans or windlasses are placed at certain points on the ground, so that a rope attached to end

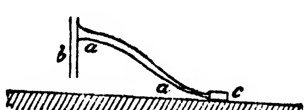


Fig. 49.

c of lever *a a* brings. the end *c* round to the point desired. Another method for turning the arms so that the sails shall always be opposed to the wind is named here, as it further illustrates the action of a fluid on oblique surfaces. The cap of the mill which carries the shafting, as shown in fig. 50, is provided with an outrigger, *a*, carrying at its extremity a flat "vane," *b*, the blade or broadest part of which stands vertically on the shaft, as at *c*. When the wind is blowing fair on the arms *d*, *d*, of the windmill, corresponding to *b c* in fig. 48, as at *e*, it passes over and past the sides of the blade of the vane *c*, as shown by the arrows; and this presenting little or no surface, only the small and thin end section, and any tendency to force it from the right hand to the left being counteracted by a tendency of precisely the same force on the other side tending to press the vane in the opposite direction, the vane is balanced, so to say, and no motion laterally or sideways is given to it, so that the position of the arms *d*, *d*, to the direction of the wind blowing right face-on to the sails from *e* remains unchanged. But the moment the direction of the wind changes, it no longer presses equally on each side of the vane *b*, as at *c*, but supposing it to shift so as to veer or come round and blow in the direction of arrow *f*, then striking upon the vane, as at *g*, the oblique action on its surface of the wind, *h*, tends to force the edge *g* outwards, but being rigidly connected with the cap, it takes a motion of circular revolution, and there is no pressure on the side *i* of the vane to oppose this, save the normal pressure of the air, which has always a greater or less ten-

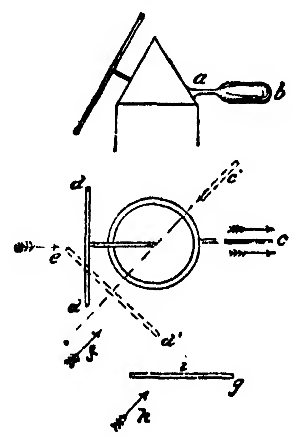


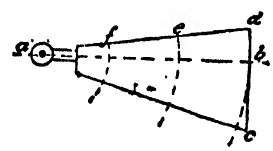
Fig. 50

dency to resist flat-surfaced bodies passing through it. We shall see presently how this very tendency is made available to regulate the motion of bodies passing swiftly through it. Whatever, then, be the direction in which the wind is blowing, the vane *b* is always on the side opposite to that direction, and the whole being rigidly connected in the normal position, as shown at *e d c*, fig. 50, the three elements represented by the vane *c*, the arms *d*, *d*, and wind *e*, are maintained uniformly in the same relation to each other; this is shown by the dotted lines. We have met with young mechanics who did not understand how a vane, as *a*, always keeps to the side opposite to that at which the wind is blowing, which in nautical phrase is the "lee" or "leeward" side, as the side on which the wind is blowing is called the "windward" side. The above explanation will show such that this tendency of a vane to keep always in one direction is one dependent upon the principle of direct and

oblique forces, of equal and opposed and of unequal and unopposed forces.

But as a vane must always have a surface large enough to give a power to carry round the weight of the cap, arms, and shafting, it will in some cases get to be of such large dimensions as to be not merely unsightly, but not available for use. Another method is therefore used in windmill mechanism to keep the arms always facing the wind, and is worthy of notice here on more accounts than one, as it illustrates not merely the principle of fluid action on oblique surfaces we are now considering, but an important principle in mechanics which has yet to receive further notice in this section. In this method of adjusting the position of the arms *b*, *c*, fig. 48, to the wind in direction of arrow *a*, the cap, as *i*, is as before movable, being supported on and running freely upon metal balls placed in a groove on the top ledge of the mill structure or tower. A circular rack is secured to the lower part of cap, immediately above the roller groove. With the teeth of this a small pinion engages; the shaft of pinion receives motion by a train of bevel-wheel gearing from the shaft, running at right angles to shaft *d* of the sail arms *b*, *c*, of the small circular vane *j* carried on the end of an outrigger or projecting frame *k*. The vane *j* is in fact a small windmill, with arms or sails placed obliquely to the central shaft, as in diagram, fig. 47. But the arms, being small in surface, are made solid throughout, and the arms or sails being once and permanently fixed to the shaft, remain always at the same angle of obliquity. The relation of this small windmill *j*, in fig. 48, to the sails *b*, *c*, and wind as at *a*, is precisely the same as that of the vane *b* in fig. 50 to the sails *d*, *d*; for when the wind is blowing directly on the sails, as at *a*, the wind presses equally on both sides of the oblique arms or sails of the circular vane *j*, so that, the pressure being balanced, no change of position is effected: this only takes place when the direction of the wind *e* changes, as at *f*, fig. 50.

The large arms or sails of the windmill, as in fig. 47, are seen to be much wider at the outer ends, as *a b*, *c d*, than at the inner, where they meet the central shaft *e*: a good proportion for the width of outer end, as *a*, is one-fourth of the diameter *b d*. The sail stops short of the centre, a distance of about one-twelfth of the diameter, as in *b d*, fig. 47, and as shown in fig. 51, at *a*. The surface of the sail-covered part of the arm is found to be most effective when arranged in relation to the centre *a b* of the arm in fig. 51, taking *a b* as the radius, when *b c* is one-third of the radius, *b d* one-sixth, the distance at *a*, where the sail stops short, being as stated above, which is equal to one-sixth of *a b*. The sails are set, as we have shown at *g* in fig. 46, oblique to the axle or central shaft which carries them, so that the force of the wind is imparted in two directions—one in the length of the axle, tending to move it end-on in the direction of the arrow *h* in fig. 44, the other in the direction from the axis *a* to the end of sail *i j*, the two resulting in a motion of revolution of the sail round the central shaft or axis *a*. If the sail was set, as in fig. 45, as various sections—as, for example, at *e* and *f*—this would give various breadths of sail surface to be acted upon by the wind. The same is found in the sail as ordinarily set, as in fig. 51, at lines *e* and *f*. The angle of obliquity, then, which would suit the extent of sail surface at section or breadth *e* would obviously not suit the surface at breadth *f*. The wind will take a longer time, so to say, to travel over the broad surface at *e* than it will at *f*; and as the sail approaches the central shaft *a*, the loss will be the effective force of the wind in turning it. And near the shaft it becomes so little powerful that the sail, as we have seen, stops short of the centre by the space *a*. To make up for this difference in the effective force of the wind at different parts of the sail surface, the angle of obliquity of the surface at different points should bear a certain proportion to the width at that part; hence the angle of obliquity should be greater



Fig, 51.

at the narrow end, as towards *a*, and gradually decrease or flatten as it approaches the end *c b d*. This is shown by the dark lines in fig. 51. The celebrated engineer Smeaton, who investigated closely the working conditions of windmills, estimated the varying angles as follows: Dividing the radius of the arm into parts of five feet, he found the best angle for the breadth of the sail at the first point—five feet—from the centre to be 18°, at the second 19°, third 18°, fourth 16°, fifth 12½°, and at the sixth 7°. To obtain the varying surface thus required to gain the utmost efficiency, the sail-covering canvas is stretched upon the framework of the arm, so that when fully extended the surface is bent or curved in the direction of its breadth, or twisted so that it presents the appearance of a screw or spiral surface, the twist being greatest near the centre and gradually lessening as it approaches the end. As the force of the wind is perpetually varying, and as the work to be done is in some respects a variable quantity also, it is necessary for equable working that some means should be within reach of equalising the effect of the wind upon the mill arms.

THE CALICO PRINTER.

The Chemistry and Technical Operations of his Trade.

CHAPTER XX.

(3) ARTIFICIAL COLOURING-MATTERS; ANILINE DYES, ETC.

The great majority of the dyes employed in modern calico printing are artificially prepared. Whilst the shades of colour forming dyes of moderate fastness obtainable from natural sources are but limited, those which are now readily produced by artificial dyes range through every possible shade of colour. It may be said that the only perfect shades of fast colours obtained from the former class of products comprise yellows and oranges (unrivalled by artificial productions), reds and pinks, dark and light blues, and black; whilst brilliant shades of blue, green, and violet, which are of the most vital importance in fabric decoration, are entirely absent from the list.

A few years ago almost all the colouring-matters applicable in calico printing were of the two foregoing divisions—namely, mineral pigments and vegetable dyes. Only recently have the achievements of chemistry revolutionised the entire industry by the introduction of alizarine and of aniline and allied dyes. No better illustration could be drawn of the aid which purely scientific research can bestow on the manufactures, than that of the production of artificial colouring-matters. The highest scientific and mathematical training have, with signal success, been brought to bear upon the practical questions of the production, on a large and profitable scale, of dyes which could compete with natural, in many cases being vastly cheaper and superior. An immense amount of German research has resulted in the discovery of artificial alizarine and of most of the aniline dyes; of English and other research, in the production of other anilines, which may be said to have revolutionised the industry of calico printing. The artificial dyes, apart from their general cheapness, mostly possess the advantage over the older dyes of being easy of application and frequently very fast. In the case of bright green, for example, in place of the numerous expensive and often poisonous greens formerly used, we have crystal aniline green, which, for economy, stability, and simplicity of application, leaves nothing to be desired.

Most of these artificial dyes are, as is well known, derived from coal tar, and such has been the effect of this utilisation in enhancing the value of the hitherto almost waste and troublesome product, that we may reasonably expect that coal will be treated for the main purpose of obtaining the tar — with but secondary attention being given to the gas and coke obtained.

For convenience of treatment—although not perhaps the most scientific arrangement, yet the most practical—we will treat of the artificial dyes under the heads Alizarine, Reds, Yellows, Blues, Greens Violets, Blacks.

A. Red Artificial Colouring Matters.

1. *Alizarine: the Principle of Turkey Red or Madder Red; the Base of Madder Lake.*

Alizarine is an organic compound, and is the colouring-principle in madder, and may, of course, be obtained from that product, by careful extraction, with solvents. Alizarine is an acid, its correct name being alizaric acid; is a deep-orange-coloured beautifully crystalline compound, insoluble in water, acids, etc., which readily volatilises in yellow flames when heated to 200° C.; it dissolves readily in alkalies to a blue or violet solution.

Manufacture of Alizarine.—The original base of alizarine is coal tar; from this substance alizarine is manufactured by a series of chemical treatments which may be roughly summarised as follows:—

(1) The Manufacture of Anthracen. When coal is subject to destructive distillation it yields coal gas, ammoniacal liquor, light oils, heavy oils, and lastly pitch and coke. The heavy oils consist of naphthalin, phenol, cresol, and analogous organic bodies, and anthracen, which is contained in the last distillation. This is subjected to a process of purification until nearly pure anthracen is obtained as a greenish paraffin crystalline-like substance is obtained, melting at 205° C. to 208° C. On carefully heating, pure anthracen sublimes and condenses in small lamellar crystals, which melt at 212° to 215°.

(2) Conversion of Anthracen ($C_{14}H_{10}$) into Anthrachinon ($C_{14}H_8O_2$). This may be affected in several ways, that generally employed being to treat 1 part anthracen with 2 parts bichromate of potash and sulphuric acid.

(3) Conversion of Anthrachinon ($C_{14}H_8O_2$) into Bibromanthrachinon ($C_{14}H_6Br_2O_2$). This is accomplished by heating 1 equivalent of anthrachinon and 4 equivalents of bromine in closed vessels, for several hours, to a temperature of 80° to 130° C.

(4) Conversion of the latter into Alizarine. The bromine derivation now obtained is treated with concentrated caustic alkali potash or soda at 180° to 260° C., whereby the bromine is recovered. The mixture assumes first a blue, then an intense violet colour, due to the formation of alizarate of soda or potash. The mass is allowed to cool, dissolved in water, filtered, and excess of sulphuric or hydrochloric acid added, whereby *alizarine* is precipitated in orange flakes, which are washed, filtered, and made into a paste or "extract" with water for the market, the strength being generally fixed at 20 per cent.

Artificial Alizarine. — Alizarin, the tinctorial principle in madder, yields with different mordants varying shades of red, violet, and black. It occurs in commerce in a paste containing 10 or 20 per cent. of colouring-matter, consisting essentially of either pure alizaric acid, or a mixture of this body with a closely allied body, purpuric acid; or it consists solely of the latter substance. The more of the latter substance it contains, the yellower is the shade obtained from it with an alumina mordant; the more alizarine, the bluer is the shade.

If the commercial alizarine extract be dried and carefully heated, pure alizarine or purpuric acid volatilise (at about 215° C. to 240° C.), and when the yellow fumes are cooled they condense into beautiful orange-yellow crystals. This is the purest form of alizarine. These crystals are insoluble in water; in solution of caustic soda they dissolve to a beautiful violet solution of alizarate of soda: most salts, which turn red litmus blue, such as carbonate and silicate of soda, etc., act similarly. When alizarine is heated with acetate of alumina, a red precipitate is obtained; with acetate of iron a black or violet precipitate; with copper, lead, tin, chromium and other metals precipitates are obtained.

2. *Aniline Scarlet, Ponseau, Amaranthe, Fast Red, Cochineal Substitute, New Red, Coccinine or Naphthalin Scarlet.*

This magnificent dye may be taken as a type of the aniline colours. It yields the most brilliant scarlet possible to obtain, or indeed possible to conceive; but unfortunately it cannot be produced fast upon cotton. If means were discovered of rendering it, or some similar compound, as fast as alizarine scarlet, it would revolutionise modern calico printing. Such a discovery, however, is not likely to be made. On wool and silk the shade yielded is equally bright to that yielded on cotton.

Naphthalin scarlet is a deep red powder, manufactured of a variety of shades, varying from orange-red and scarlet to very blue shade. It is very readily soluble in water, giving a bright, deep, scarlet-coloured liquid, which readily imparts its colour to starch paste, forming the "colour" used for printing cotton "loose steam work." The colour obtained of course readily washes off in cold water, but it resists moderately well the action of light, and hence is much used in printing window cretonne curtains.

There are a great variety of aniline scarlets in the market, differing but slightly from each other, and known by a still greater variety of names. Aniline scarlet is manufactured by the eminent firms Meister, Lucius & Bruning, The Farbenfabriken (late F. Bayer & Co., Brooke, Simpson & Spiller, etc.)

3. *Magenta, Rosaniline, Fuchsine* (pron. few-sheen), *Aniline Crimson, or Rubine* ($C_{20}H_{19}N_3$) HCl.

This dye was first manufactured in 1856 by Hofmann, by the oxidation of aniline, by treating with chloride of carbon at 170° to 180° C. for several hours under pressure. The product obtained by Hofmann was impure; it is now made both in this country and in Germany in a state of purity.

Magenta occurs in commerce in the form of beautiful green crystals, of accurate formation and of metallic lustre; they readily dissolve in water, alcohol, or acetic acid. The solution, when printed with alumina, yields an exceedingly pretty and well-liked shade of crimson, or pink or red of a very blue or violet shade; with tannic acid a less bright but faster red is obtained. Magenta is very loose both to soap and light, and to acids. It is much used in compound colours, such as chocolates.

Many varieties of magenta are sold; some are called "cerise," "aniline chocolate," etc., which are simply impure qualities of magenta, or slightly modified compounds: thus, a product known as *phosphine* is the *nitrate* of rosaniline ($C_{20}H_{17}H_3$) HNO_3, instead of the *hydrochloride*; rosaniline is the *hydrate* ($C_{20}H_{19}N_3$) H_2O.

Magenta is manufactured by the firms of Meister, Lucius & Bruning, Roberts, Dale & Co., Manchester, The Farbenfabriken, etc.

4. *Saffranine* ($C_{21}H_{20}N_4$) HCl.

This beautiful dye has been named after the natural product safflower, which it resembles in shade—namely, a delicate pure pink of a slight blue or violet shade. Saffranine of good quality is a chocolate-coloured powder readily soluble in water, alcohol or acetic acid to a fine red solution, which, when printed with alumina mordant, yields a magnificent bright pink, but which, like magenta, is loose both to light and soap. Saffranine has the curious property of turning to a beautiful blue colour with strong hydrochloric acid, returning again to red or pink when sufficiently diluted with water.

5. *Eocine* ($C_{20}H_8Br_4O_5$).

Eocine is another magnificent dye derived from coal-tar compounds. The shade produced on cotton by this dye is not exactly similar to that of aniline scarlet, and in properties it differs considerably from that substance. It cannot be effectually fixed upon cotton, but on wool it is not so loose, especially when mordanted with lead, with which eocine forms a stable scarlet lake or precipitate of great brilliance, and generally known, when prepared as a lake, under the name of "vermilionette." The chief use of eocine in calico printing is that of yielding a red discharge when printed along with tin crystals, etc., on manganic bronze cloth; the eocine is not destroyed by the acid of the tin salt.

THE MACHINE MAKER OR GENERAL MACHINIST.

SPECIAL EXAMPLES OF HIS WORK—ITS LEADING TECHNICAL PRINCIPLES AND DETAILS.

CHAPTER VII.

IN connection with the subject opened up in last paragraph of preceding chapter, we have to remark that a train of very curious mechanical suggestions is here brought up by the consideration we there named, for it involved the problem how to give accuracy to mechanical construction, hitherto unattainable, by the use of machine tools possessing this accuracy, and which therefore had themselves to be made with rigid precision. If the technical reader will think this position out, looking at it all round, he will find —probably somewhat to his surprise, certainly to his practical advantage—that a great many lessons of practical value to him as a maker as well as a reader can be got from it.

What under the point we are now considering we wish to direct attention to is this: that all the early forms of mechanical construction we have referred to were brought out by the practical mechanic or machinist, quite independently of the theorist or purely scientific man, not aided by but rather in spite of, so to say, what literature said to be mechanical was at his command. Such literature was certainly possessed of the "heavy metal of mathematical formulæ and calculations," to prove the power, or as we should perhaps call it the theoretical possibility, of an arrangement of the "mechanical powers" by which "a power which is much less than the one-hundredth part of a pound will bee able to move the world,"—those "mechanical powers" bearing, if we may so say, the same relation to the laboured disquisition of the theorists who wrote such ponderous treatises on what was called mechanics as the boxes, the jars, and other paraphernalia of the conjurer to the sleight-of-hand tricks with which he astonishes his gaping audience. But of any real help to the working machinist in suggesting machines which would be, not to say possible, but practical and useful, none was offered in the pages of those portentous volumes. Far less could the machinist gather from them, if we can conceive of him referring to them at all with any such vain hope in his mind, any remarks upon or practically available suggestions connected with the parts of the machines and the dimensions or forms which they should have in order to gain the strength required to do the work for which they were designed. Such a matter of strength was far too material a consideration for those who dwelt so much in the clouds, and built there so readily their mechanical castles. And if one of those early writers condescended to consider this point at all, he deemed it one of such indifference, or of such easy attainment if desired, that it might be left quite out of his calculations as to what was necessary to be given in his pages. How little the actual daily work of the machinist, and the difficulties it brought with it, were thought of, may be gathered from the following sentence taken from an early work profuse in its marvellous machines. "It were needlesse," says the writer, with amusing nonchalance, "it were needlesse to set down any particular explication how such mechanical strength may be applied unto all kinds of local motion; since this in itself is so facile and obvious that every ordinary artificer doth sufficiently understand it." If it be true that one half of the world does not know how the other half lives, it is no less true in regard to how people work. Had this writer—a type of nearly all the early writers on mechanical subjects—known more of the actual working life of the "ordinary artificer," he would have found it to be quite a different thing from what he thought of it, if, indeed, he gave any true thought to it at all. Much more "facile" (*facilis*, from *facere*, to make) was it for him to build his mechanical castles in the air than it was for the "ordinary artificer" to apply properly "mechanical strength" to his local motions, who, if he did "sufficiently understand it," did so in very rare cases, and only through hap-hazard rule of their conjectures, or after infinite and painful experience. It would have been well for that union of "practice with science" which has done so much for the machinist of modern times, had the scientists of the early times come down from their high regions in which they soared, and mixed with those who carried on what they deemed to be the "prosaic work" of the practical life of the "ordinary" artificer. They would have found that such matters as they pronounced "facile" and "well understood" were neither so easy nor so thoroughly comprehended.

It is even now forgotten that the above-named well-known aphorism is capable of two readings; and we fear that the scientific man not seldom opines that what is really wanted is that practice should avail itself of science, forgetful of or ignorant of the fact that science would be greatly the better frequently for being taught by practice. It is not so long ago that a profoundly scientific man left London for the provincial seat of a well-known manufacture, with the avowed purpose of shedding the light of his knowledge on its darkened regions, and of showing the workmen the depths of their ignorance, and how he could save them from its results. It took no long time for him to be made aware—and probably painfully, as the truth would scarcely be palatable to his scientific *amour propre*—that the much despised rule-of-thumb practice derived from and wholly the result of generations of working experience was in reality truly scientific in its basis, and that it bristled, so to say, with points all essential

to practice of which he had been wholly ignorant. In place, then, of asking the workmen to come to his school to be taught, he felt that he had the greater need to go to them to be taught what would in fact enable him to teach them better.

Union of Science with Practice in Mechanical Work.

This union of science with practice, viewing it also in an inverted order in regard to the work of the early machinists, was long in being consummated, and the relationship or bond between the parties—the man of science and the man of practice—was at first of the slenderest nature. Many years passed away before the scientist seemed to have any definite conception of the fact that all his laboured descriptions, his intricate diagrams, or his pictorial representations of possible and impossible machines, and his puzzling, perplexing mathematical calculations, were and could not be of any practical service to the work-a-day world. For long, indeed, it seemed as if scientists dwelt in a region exclusively their own, in which work to be done was the last thing to be thought of—as, indeed, this work not to them existing, thought was quite unnecessary. And when, in course of time, the truth that they did dwell in the dull regions of humanity, where work and painful work had to be done—men being impelled thereto or "compelled by the stern necessity of living"—dawned upon them, the help they gave was for long of a very meagre kind, and could be availed of by the practical man in but a very limited way. Nor was it likely to be other than this, for however ingenious the theories on which the strength of parts of machines or machine structures were based, the formulæ given in connection with them could and did have no value to the practical machinist; as accurate data in connection with the materials of which those parts were made did not exist—at least, had not been recorded by practical men, the majority of whom, indeed, did not deem the matter worthy of that close attention necessary to get trustworthy facts worthy of record. It was long before the truth dawned upon the minds of scientists that the first thing they had to do was to take the materials used by the machinist, ascertain their constructive peculiarities, thereafter to put them to the tests of bearing weights or active pressures or forces, which might be applied to them in doing the work for which they were designed. Data would thus have been obtained by which rules could have been based—those being known now as the "constants" applied to the formulæ by which calculations of the strength of materials were made. When this great step in work, which, whether the theorists liked the term or not—and we can judge from what has been said that they were at the least rather chary of having it applied to them—was essentially *practical*, quite a new era in the history of the art and science of machine making was opened up. And the technical reader will at once perceive that this union of practice and science opened up a wide field of investigation and observation, which, although it of course existed, had never been really entered upon. The very attempt to find "constants"—as, for example, that to determine the breaking weight of a beam—would, as of necessity, direct attention to the fact that differences in the value—the *constructive value*—of materials existed in practice; and to put the matter in the familiar, yet most suggestive way expressed in the paraphrase of a well-known foreign proverb, there "was iron *and* iron," for example, steel *and* steel, timber *and* timber: in other words, one lot or piece of any one of those materials might not be of equal constructive value with another lot or piece, the truth being much more likely, in those the early days of the manufacture, say of iron, that there was a great difference in their value. Even now, when such improvements have been made in the manufacture both of iron and steel, there is anything but uniformity in the constructive value of lots made by different makers, or even in different lots or parcels made by the same manufacturer at different times. Again, although we have now "constants" for the expression of the constructive value of different kinds of timber, which have been deduced from the experiments carefully made by scientific men, the fact remains that, in doing their work with them, machinists and others, merely by their rule-of-thumb methods, had in large degree anticipated the results of those experiments, and had, at least in a rough fashion, determined the values of the different kinds for certain classes of work. Thus it happened that at one time—and although we are so far advanced this holds true with many machinists of the present day—all materials of the same class were taken to be of the same value: if a rod of iron gave in one machine a certain strength, an exactly similar rod would be looked upon and treated as if it were precisely of the same constructive value. Iron was iron, and nothing else, therefore one piece of iron was as good as another; and although at times a somewhat disagreeable shock, and one costly in its results, was given to this pleasingly comfortable belief by some thoroughly bad piece of metal giving way when least expected, still as a rule then, and to some extent it still is so now, machinists were quite content to go on from day to day using materials in the belief, if not expressed at least mentally held, that their makers would give them, if not the best of "stuff," at least that which would be so uniform in quality that practically it was not worth their while to inquire into the matter to see whether it was so or not.

THE GRAZIER AND CATTLE BREEDER AND FEEDER.

THE TECHNICAL POINTS CONNECTED WITH THE VARIETIES OR BREEDS OF CATTLE—THEIR BREEDING, REARING, FEEDING, AND GENERAL MANAGEMENT FOR THE PRODUCTION OF BUTCHERS' MEAT AND OF DAIRY PRODUCE.

CHAPTER XXIV.

The Grazing Question.—Improvement of Grass Lands.

WE have devoted several paragraphs to a general notice of the two systems of cattle feeding and rearing known as (1) grazing, otherwise and more popularly termed pasturing, and (2) stall or house feeding. The features of each of these two systems were there pretty fully discussed, and several of the details of their practice given. However worthy the best consideration of the farmer the permanent stall or house feeding system may be, it is at present quite an exceptional practice—grazing or pasturing of stock, alike of fattening cattle and of dairy cows, being the rule in the practice of British farming. That these two systems will remain in this relative position of importance is likely to be the case for a long time. It is therefore a matter of great moment that the best method of carrying out the practice of grazing be thoroughly understood. To say that in this department of industrial or technical work there is a right and a wrong way of carrying it on, and that but too many, unfortunately alike for their own interests and those of the nation at large, adopt as a rule the wrong method, is only after all directing attention to a peculiarity of business method by no means confined to farming, but met with in every branch of trade. While not at all inclined to take a pessimist view of the matter—that is, professing to look at its worst side—there is but little doubt of the fact that many so-called practical men seem to be quite satisfied with little more than the fact that they are carrying out the practice of "grazing," as if "the name of the thing" were all that was essential, and are not desirous to inquire whether it is grazing upon correct principles, and, indeed, as if they considered that it had no principles at all by which its practice could be guided. There are, on the other hand, not a few—we are inclined to think, taking the results of practice all round, they are the majority—who carry out grazing in such a way that if they do not secure all the advantages which the system is capable of giving, secure them to a great extent; while there are a few who in their practice show what may be called the perfection of grazing. From what such authorities have done, and the manner in which they do it, we are enabled to formulate a set of rules or principles of practice which will be of great service to the grazier, and indoctrinate the student with much of what it is essential he should know.

And here it is necessary to point out the fallacy of the opinion held by many farmers, and certainly by the popular mind, that if land be but grass land it is fitted for the grazing of live stock; one farm, according to this notion, being quite or very nearly the same as another farm, so far as the quality of the grass taken as a whole is concerned. It is forgotten that, to paraphrase the French proverb, which reminds us that there are "faggots *and* faggots," so there are grasses *and* grasses; that while one grass field may present food for stock of the most nutritious character, another will yield grass of a kind totally the reverse. And, so far from the advice being given of which one has heard so much lately—"Convert your arable land into grass pastures"—there would, so far as concerns not a few farmers, be more sound counsel given to those who possess grass lands, if they were advised thus: "Improve them, make them much better for the stock you do keep, and on the same land you may keep more stock, or what will be the same thing in effect, the same number of stock you do keep will pay you better, as they will be fed better." Important as this point will on consideration appear, there is more in it than it even presents at first sight. For it is not only that what grasses are prevalent in, or in fact constitute the pastures, may be in good condition—that is, be well cultivated—but it is also that those grasses are fitted for cattle feeding. For it should be remembered that one may give his best ability to doing work, but if that is not of the kind required, his labour is but in vain. There are weeds, and grasses; but there are some grasses which, so far as nutritive or feeding qualities are concerned, are but little better than weeds, so that while to keep lands having grasses of this character free from what on all hands is admitted to be weeds may be, and is in a certain sense good, inasmuch as, so far as it goes, it is careful farming, it is not the kind of farming which is required. The grazier, therefore, should possess a good knowledge of the different kinds of grasses. On this point we may have some practical remarks to offer in future paragraphs. Meanwhile we proceed to draw the attention of the student-reader to some other points necessary to be considered on the subject of grazing.

Improvement of Grass Lands (*continued*).

It is not enough, as we have seen, that the kinds or qualities of the grasses should be good, that is, nutritious, to begin with; but if these good qualities are not naturally present they should, by judicious selection and management, be added to the land in the way hereafter to be noticed. It is equally necessary that by attention and careful cultivation the good grasses should be kept in the highest feeding condition. This is secured by having the land always in that condition which is known to practical men as "clean." This quality is only obtained by a constant looking

after the condition of the fields, by keeping down the weeds, and by the judicious addition of manures—which are, of course, applied in the form of what are called "top dressings" (see "The Farmer"). We are well aware that while many farmers do not grudge abundant manuring to meadow lands, so as to have large crops of hay, they seem to think it quite unnecessary to add to the richness of their pasture fields by a like liberal manuring. This is, however, a great mistake. For where grasses are either naturally good in pastures, or made good by judicious "seeding," they will be greatly improved by the application of proper manures—that is, suited to the soil. And it is a suggestive consideration under this head that where pasture lands are much infested by weeds the application of manure top-dressings has very frequently the effect of killing the weeds. Nor is it a less significant point to note in this connection, that not only are weeds killed and the good grasses improved, but grasses make their appearance which before were absent, as if the weeds had occupied their places or prevented them from coming up. For it is a singular fact that grass seeds or roots—and this often applies to weed seeds and roots—may lie dormant in a soil for years, and, so far as we know, would continue to do so perpetually till the land, for some reason or other, has been broken up or ploughed. This is indeed one reason added to others why old pastures, thoroughly worn out or exhausted or overrun with bad grasses which cannot be replaced by good ones, and infested with weeds which cannot be got rid of, should be broken up, and the land thoroughly cleaned and prepared for a new laying down of a permanent pasture with seeds appropriate to the soil and locality.

Peculiarities of Grass Lands.

It is one proof of the fact that farming in any one of its branches is not the easy, happy-go-lucky calling which it is popularly supposed to be, but that it is one demanding great skill and no small amount of scientific knowledge, that amongst the obscure points about which we shall probably know more in the future in connection with grass land is this: that of lands placed, as far as we can judge, under precisely the same circumstances, and having the same cultural peculiarities, and receiving what is called good farming, some will keep up in quality of grass—indeed, will to some extent improve—while others will gradually go back and get so deteriorated that breaking up and re-seeding may be the only thing left to be done. There are many things conducing to this deterioration of which we can only conjecture; but one cause is but too frequently lost sight of—and that is, that the lands may have been badly drained at the first, or if the plan of drainage was good, the details of its work may have been so bad that the drains gradually got out of order, and from well drained, and in so far as good drainage is an active agent therefore highly productive, got ultimately into a badly drained and therefore unproductive condition. From this the student will infer, and rightly, that grass lands ought to be carefully drained. There are acres upon acres of grass land, so called, throughout the kingdom, which, even to an inexperienced eye, are seen to be of wretched quality, yet which, if drained properly, would become highly valuable. For it is not that the soil is defective, or the climate or locality bad: all may be and often are good, sometimes of the best, and capable of yielding the richest of pastures; but the grasses will not grow, the soil produces chiefly coarse, rank herbage, and over its surface are dotted here and there clumps of aquatic plants, such as the well-known "rush," which tell as plainly as they can of what is in reality a wanton waste of that which is inherently good. Drainage, then, is essential; good grass land cannot be "made" without it; and out of what are now good, bad or indifferent may result if the drains cease to be thoroughly effective in operation. The necessity for most effective drainage in grass lands arises not merely from its getting rid of stagnant and excessive water in the soil, but also its admitting the highly beneficial influence of the atmosphere to act upon it, for this alone can be done in the case of grass land, which cannot be opened up like arable land from the surface, through the agency of the underground channels afforded by the drains. How important a part the atmospheric agencies play in all vegetation the reader will see by referring to the paper entitled "The Farmer."

The Weeds of Grass Lands.

In a preceding paragraph in this chapter we have referred to the influence which good manuring has upon grass lands in getting rid of weeds. Where the fields are much infested with the weeds so prevalent almost in every locality—as the dock, the plantain, the ranunculus or buttercup, the thistle, and that coarse-leaved yellow-flowered plant so well known to and so graphically described by the Scottish farmers as the "curse of Scotland" (it being said that it was unknown to that country till taken into it by the English horses of the army of the Duke of Cumberland at the time of the Rebellion)—special means may have to be taken to get rid of them. Where the land is very foul with all these weeds, worse than merely and evidently worthless, inasmuch as they keep down the grasses which are so far good, it is often well "scarified" or opened up with the tines of a cultivator or grubber.

THE IRON MAKER:

THE DETAILS OF HIS WORK AND THE PRINCIPLES OF ITS PROCESSES.

CHAPTER XIV.

The Hot Blast for Iron Blast Furnaces *(continued)*.

AT end of preceding chapter we referred to the first attempt by Mr. Neilson, of Glasgow, to heat the air sent into the blast furnace. The contrivance this gentleman employed in the first instance was very elementary and simple, as the appliances of important discoveries and inventions generally are, till a wide experience leads to more perfect arrangements. The first heater employed by Mr. Neilson was apparently suggested by the ordinary retort of a gasworks, or, as some suppose—with, however, a less approach, as we think, to the actual fact—by a steam boiler of the shape very largely then used. The retort-like vessel was made of wrought iron and inclosed in a furnace some four feet long, three high and two wide, which furnace supplied with fire quite heated the exterior of the iron vessel precisely as the gasworks furnace heated the retort. A tube or pipe was connected at one end of the iron heater, and at the other to the delivery pipe of the blowing engine. At the opposite end of the heating vessel a tube was attached leading directly to the blast furnace *tuyères.* The air thus blown through the heating vessel in the special furnace was then raised in temperature—some 140° Fahr. above the normal temperature of the atmosphere, which we may assume to be 60°. But this temperature of 200° at which the air entered the blast furnace, although so much higher than that of the ordinary air, by no means satisfied Mr. Neilson. He soon saw that another and a more carefully thought out form of heating vessel furnace was required. The first improvement made was the substitution of cast iron for the wrought iron at first used in the construction of the vessel through which the air passed to be heated. This cast iron lasted much longer than wrought, and obviously lent itself with greater ease and economy to any peculiar form or shape of the heating vessel which experience might show to be best. After repeated trials Mr. Neilson at last hit upon a form of heating vessel and furnace which with greater or less modification contains the germ of all, or very nearly all the hot-blast furnaces or "ovens," as they are very frequently, if not generally called in the trade—which by succeeding inventors and iron masters have been from time to time introduced. The principle of this improved form we illustrate in fig. 7, Plate CLVI. A series of arched cast-iron pipes or tubes, *a, a,* were placed over a furnace, the fire-grate and -place being at *b b*, the flame and heated air from the fuel in the grate coming in contact, as at *a a,* with the lower and side surfaces of the tubes *a, a.* Running along the length of the furnace were two horizontal pipes, *d* and *f*, lying on and imbedded in the brickwork of the furnace. These pipes were furnished at intervals along their length with short vertical tubes or socket pipes, corresponding in number to the arch tubes *a, a*, the ends of which were placed in the socket pipes—spigot and faucet fashion—somewhat as shown in section at *e.* Into one of these horizontal pipes, as the one at *d,* the air was forced by the blowing engine, and compelled to pass along its length, and finding no other outlets, also up and over the arch pipes *a, a* ; it was then taken up by the other and opposite horizontal tube *f*, and and led by a pipe *g* directly to the *tuyères* of the blast furnace. The reader will perceive the ingenuity by which a large heating surface was obtained in a comparatively small space. So effective was the apparatus, that a temperature of 600° Fahr. was obtained by it—a degree of heat which fully entitled the air passing into the blast furnace to be entitled a "hot blast." Although this temperature had been attained by another and a preceding design of Mr. Neilson, in which the feature was simply what might be called an elongated retort or long heating pipe, still the temperature was secured by a much more economical furnace. Thus the new furnace, as in fig. 7, Plate CLVI., gave the same temperature as the one which preceded it, with about two-thirds of the heating surface per *tuyère* and with less than one-half of the area of fire-grate. We have said that the improved form illustrated in fig. 7, Plate CLVI., was the germ or stock of all or nearly all the forms of hot-blast ovens which have been since introduced into practice. Fig. 5, Plate CLVI., illustrates a later arrangement of hot-blast oven, in which the same principle of arched heating pipes is embodied, but in a modified form. This will give the reader a fair idea of the general principle of arrangement of the ovens now in use.

So successful was the hot-blast principle, and so rapidly did it recommend itself to the iron masters throughout the country, that it very shortly so altered the conditions of working blast furnaces as to practically revolutionise the trade. But high as the temperature obtained by the system was, so manifest were the advantages obtainable by the use of highly heated air for blast furnace working, that the desire rapidly extended to have the means of obtaining a temperature still higher. And so successful have been the efforts of our scientists and practical men in this direction, that means are now in daily use by which the blast is delivered to the furnace at temperatures more than twice as high as that obtained by the most effective form of hot-blast oven on Mr. Neilson's principle, as above explained. It is a very usual thing to be met with in practice that the air sent in is at a temperature of 1300° to 1400° Fahr., and with a certain

system a temperature is obtained much higher than this. Ordinary readers will have a difficulty in conceiving of a temperature like this, which can of course only be measured by the special instrument termed the "pyrometer," the usual form of quicksilver thermometer being quite inapplicable.

The forms of apparatus by which this exceedingly high temperature is given to the blast are varied, but they all depend upon the principle of the Siemens regenerative furnace. But in blast-furnace practice the apparatus employed to produce the hot blast are not always, and now but comparatively seldom, dependent upon the direct consumption of fuel in a special furnace which forms part of them. In nearly all cases of improved working, those blast heating furnaces are fed or supplied with gas—technically termed "fuel gas" —the employment of which gives the exceedingly high temperatures we have around us now being daily used in the iron trade. And a singularly curious exemplification of the adaptation of the principle of utilising the waste products of a process so as to form the money-saving products used in another is afforded by the history of this method of obtaining high temperatures not by the combustion of fuel in its ordinary solid form of coal or of coke, but in its gaseous condition. And this illustration is all the mora curious, inasmuch as the waste products of the blast furnace itself are used to supply it with a blast of the high temperature now employed in modern iron making; so that while we have waste at one end of the process we have economy at the other. How this source of economical working is derived from the waste working of the process of iron making opens up a curious chapter in its history. Interesting and practically suggestive as the details of this would be, we are through lack of space compelled to pass it over, regretting this all the more as the reader would have to hunt up a wide variety of works and wade wearily through their pages before he would have before him a consecutive series of the facts of the case. We pass on, therefore, with some reluctance to the more practical points connected with the

Utilisation of the Waste Gases of Blast Furnaces for Furnace and Boiler Heating.—Gaseous Fuel.

We now glance at some of the details of this system of utilising what otherwise would be, and formerly were, waste products. In looking at any illustration of a "blast furnace," and in glancing over what we have given in a preceding chapter in the present series of papers, the reader may conclude that it was not a very difficult problem to solve to arrest, and, in arresting, to take down to a lower level the gases combustible and incombustible found in the blast furnace. But further consideration will show that there were many difficulties in the way of an easy solution. Like all work of the kind, the first work done was purely tentative; for the iron masters, anxious to utilise the gases, had everything to learn in connection with their use. The mere volume, enormous as this was, of the gases produced in the working of a blast furnace, and the high temperature at which they passed from the furnace, difficult as they were to deal with, could have been by many contrivances arrested and led to the lower level,—in one sense easily enough done. The appliances at first used in this connection were pretty numerous, but none were successful to the extent desiderated. The most obvious way was to cover in the top of the blast furnace, connect a pipe with the cover, and bending this pipe, lead it and its contained gases down to the general level where they were to be used. This is illustrated in diagram, fig. 4, Plate CLVI., and represents one of the early plans introduced; in this *a a* is the upper part of the blast furnace, the throat *b b* of which is gathered in with an arched cover *c c*. In the centre of this a circular hole was made, from which a pipe *d d* passed vertically up a short distance, and then was led by a curve downwards; side and circular flues, as at *e* and *f*, led other supplies also to the pipe *d*, which was called technically the "downcomer." But the greatest difficulty met with was to adjust the method of so far closing in the furnace top as to arrest and lead off the gases and yet to allow of the furnace being fed with the materials necessary for the process of reduction or smelting—the ore, the fuel, and the fluxes. For just in proportion as the closing in and thus easily arresting the gases was complete, so in proportion obviously was the difficulty of having an opening or openings through which the material of the "charge" to the interior of the furnace could be supplied. The two in one sense were entirely antagonistic. In diagram A, fig. 4, Plate CLVI., the openings *b*, *b*, in the arch or cover *c c* were left outside the pipe *d*, which led off the gases to the "downcomer" *d*; and through those openings, as shown by the arrows *c b*, *c b*, the materials were passed to the interior of the blast furnace, the "tipping" or throwing in of the "charge" of the furnace materials being always done, as our readers will recollect, from the gallery surrounding the highest part of the furnace. Those side openings in *c c* were of necessity required, in the arrangement shown in diagram, fig. 4, Plate CLVI., to be always open, so that through them a large amount of the heated gases escaped to the atmosphere and was lost. But this at the first, when gases began to be utilised, was not deemed to be a disadvantage, as all that was attempted or indeed considered necessary to be done was to arrest part only of the gases, allowing the great bulk to be lost. In diagram B, fig. 4, Plate CLVI., this partial method is further illustrated, the arrangement showing the principle of one of the early

plans. Here the central part of the upper end *a* of the furnace was left wholly open or clear in the ordinary way, to admit of its being charged easily, as shown by the arrow *b*; but an annular flue *d d* ran round the furnace, which was gathered up at the point *e*, leading to the "down-comer" *f*. Here, while the great bulk of the gases escaped at the throat in the usual way, and was lost in the general atmosphere, such gases as did pass off by the flue *d d*, entering at *c*, were considered to be the legitimate product of the system, and a greater supply was not desired nor expected. Plan after plan was introduced and tried, and each trial showed all their weak points; but the difficulty of reconciling the two antagonistic claims remained: first the claim of the gases, which required a furnace top more or less covered in or closed in, in proportion as a greater or less volume of gases was required and secured; and secondly the claim of the "charge" or materials required for the smelting or ore-reducing process was still more and more felt. For in the working of the blast furnace, as in that of every other process, there was a right and a wrong method; and to secure the right method of supplying the charge—the fuel and flux—was found to be no easy matter. We have referred in a preceding chapter to the evils accruing from the tendency of the blast furnace to "scaffold"—that is, to produce what may be called shelves or platforms, and doubtless the scaffold or projecting parts of refractory substances formed by the materials themselves of the charge gave the name to this characteristic. This scaffolding prevents the uniform gradual and easy descent of the charge or materials from the upper part of the furnace, at which they are fed or supplied, down through the whole range of furnace interior till they reach the zone of reduction. This proper descent of the charge is what every iron worker aims at securing; and it is found that a great deal depends upon the way in which the materials are fed into the upper part of the furnace: if "tipped in" in any fashion—as, for example, where there is more material supplied to one side of the furnace than to the other, or if the form or "lines" of the furnace itself tend to give unequal spreading of the charge—this scaffolding exists to a greater or less degree. By a "happy thought," or by thinking and reasoning the matter out, or by experimental trial, it was discovered that in place of tipping or throwing in the charge, as at *b* in diagram B, fig. 4, Plate CLVI., leaving it to adjust itself in the furnace as best it could, if the charging mould of the furnace was formed with a central cone, *a b c* in diagram C, the charge sliding or led off its surface was distributed in a circular direction all round the furnace, tending towards the circumference but collecting in a heap in the centre, as when feeding, on the plan shown in the diagram B. The arrows show, in diagram C, how the charge is distributed circularly by the cone *a b c*.

Utilisation of Waste Gases of the Blast Furnace (*continued*).

Now, while it was found that this arrangement contributed greatly to the proper distribution of the charge in the furnace interior, as it was made from time to time, a perhaps still happier thought led to the discovery that the cone-shaped furnace feeding mouth lent itself most admirably and completely to the system by which a perfect "seal" could be made at the feeding mouth, and which enabled, if desired, the whole of the gases to be led to the "down-comer." The diagram C in fig. 4, Plate CLIV., will illustrate how this happy combination of a good feeding mouth and a close and complete seal for the arrest of the gases was secured. Let *a a*, fig. 3, Plate CLXXXIII., be the conical feed corresponding to *a b c*, fig. 4, Plate CLVI., diagram C; but in place of being fixed, as thus shown, it is suspended by a chain, *b*, which passes over a pulley or pulleys, and by a simple mechanical arrangement of quadrant lever and counterbalance weight can be raised or lowered as required. The cone *a a*, technically now called the "bell," fits into the gallery or throat *c c*, cased with cast iron so as to form a "seat" for the "bell," and which seat or casing is called the "cone." The diagram shows the bell in its seat, or the bell and coil in connection, in which position the "charge" or materials of the furnace are when tipped in from the gallery above, being kept at *d*, in the upper part of the cone. This completely fills up the usual mouth or throat of the furnace, so that none of the gases welling up from beneath can pass out at *d d* to the atmosphere and be thus lost. But below the base of the bell *a a*, openings, as *e*, *e*, lead the gases into an annular or ring flue, which takes into a flue, *f*, and from thence into the "down-comer." In practice there is a small-diametered pipe connected with the flue, which is led vertically up and terminated with an open orifice—regulated in some cases by a flap valve. A portion of the gases pass up this small tube, and flashed into flame are lost in the general atmosphere. When the observer sees the flame at top of this small pipe he may take it as representing the volume of the gases which are not taken into the "down-comer," or what may be called the residue of the general supply not required for use. When the furnace requires to be charged with the ore, flux, and fuel, the "bell" *a a* is lowered, and the charge lying in the space *d d*, above it, is shot into the furnace, sliding over the bell surface, this for a brief space making a more or less complete opening for the gases coming up, as at arrows *i*, *i*, to pass into the atmosphere. But the interval during which the cone is lowered is or may be made very brief; and the charge passing down itself partly

blocks up the passage for the gases escaping; the base of the bell, *a a*, still further prevents the gases from passing out, and deflects them into the flues *c, c*. This "bell and cone" feed apparatus and gas arrester is now the most largely used.

In employing the gases of the blast furnace as a means of heating the boilers and raising steam for the blowing engine, the arrangements and construction, so far as the furnaces and boilers are concerned, are precisely the same as when coal is the fuel used. The furnace fittings required for coal burning might no doubt be dispensed with, as they are in no way essential to the employment of gas fuel as a heating medium. But it is deemed advisable to retain them in every case, so that in the event of anything happening to the "down-comer" or to the gas appliances generally, thus stopping the supply of the gas fuel, the boilers can be kept working by burning coal in the usual way. So perfect are the arrangements now made for using gas fuel for steam-raising purposes, that the inconveniences and in some instances the dangers arising from the use of such highly explosive gases are now quite overcome; and in well arranged systems of boilers, where the flues are very long, a complete body of brightly burning gas is maintained, even to the extent of sixty feet.

Employment of the Gases to heat the Air for the Hot Blast.

Having in last chapter explained the method by which a large supply of combustible gases is obtained from the blast furnace, and how they are used generally and on the largest and most effective scales for the raising of steam to work the blowing engine, we have now to glance at the method of using those gases for heating the air from the hot blast itself. The most obvious way would be to adopt the gas to the ordinary hot-blast oven, as already illustrated. But economical and effective to a certain degree as this might be, a much more effective and still more economical method is by using the gas in connection with special furnaces in which Siemens' regenerators play an important part.

There are various forms of furnaces for this purpose in which the regenerative principle is carried out. The two best known, if not the most largely adopted, are the "Whitwell," invented by the late William Whitwell, of Stockton-on-Tees, and the "Cowper," invented by the well-known engineer of London of that name. There is in the different forms of regenerative hot-blast furnaces, or "stoves" as they are more generally called, what may be called a strong family likeness common to them all—the differences between each lying in how the chambers, flues and regulating valves are arranged, and in the constructive details of those different parts. Externally they present the appearance of columns or cylindrical shafts of which the height greatly exceeds the diameter, the whole of the heating arrangements being contained within the shaft or column. As giving the reader a good idea of the arrangements and construction of this, one of the most important applications of the Siemens regenerative principle, we have selected for illustration a form in which there is a combination of the leading parts of the best-known stoves—and which is known as the "Siemens-Cowper-Cochrane" system. This has been introduced into American practice with marked success, and is fully described in a paper, profusely illustrated, by Mr. Hartmann, given in a recent number of the "Transactions of the American Institute of Mining Engineers." To this paper we are indebted for the materials of the following illustrations and descriptions. Fig. 6, Plate CLVI., is a part vertical section, and fig. 1, Plate CLXXXIII., a horizontal section or sectional plan: these show the general construction and arrangement of this form of regenerative stove.

It consists essentially of an iron central air-tight chamber, coated internally with red brick and fire brick. This iron cylinder, *a a*, contains the flame-flue *b*, near one side, as shown in fig. 1, Plate CLXXXIII., and this flue or combustion-chamber is partially surrounded by a regenerator, *c c*. In the chamber *b b* the gas undergoes combustion, and as this goes on the products are distributed over the surface of the regenerator *c c*, in order that the heat they contain may be absorbed, When the gas passes out, after doing its heating duty, its temperature does not exceed that of 250° Fahr., supposing the air which goes to form the temperature of the "running blast" to be 1200° Fahr. The regenerator *b b* consists of brickwork perforated over the entire surface with close-set openings four inches square; as shown in plan in fig. 1, Plate CLXXXIII. The bricks are of small size—about three inches in thickness. The reason of the small size of the bricks is evident enough when we remember that large bricks would not so readily absorb the heat, and that that which is absorbed becomes partially lost, because stored up in a form not readily available. A large surface is essential, moreover, to the economical working of the stone, were it only for the reason that the defect of *glazing* would result with large bricks from too high a temperature, and so cause irregular absorption and consequently irregular radiation. It must be remembered that any surface of brick which is in direct contact with burning gas becomes useless as regards its heat-absorbing power. This is explained in the glazing process which always happens when the gases are completely burned and in contact with the brick. Glazing, however, of the walls of the flame flue or combustion chamber is an advantage, as it serves as a protection to the bricks.

THE FACTORY OR MILL HAND AS A TECHNICAL WORKER.

THE ORGANISATION, GENERAL DUTIES, AND SPECIAL WORK OF THE STAFF OF FACTORIES FOR THE PRODUCTION OF SPUN AND WOVEN GOODS—THAT IS, "YARN" AND "CLOTH"—AND THOSE CHIEFLY IN COTTON AND WOOL—GENERAL DESCRIPTION OF THE VARIOUS PROCESSES OF MANUFACTURE.

CHAPTER XV.

Throstle Spinning (*continued*).

THE reader, though unacquainted with the practical part, or working of cotton, will perceive the necessity of the changes in the machinery under the circumstances specified at the conclusion of our last chapter. The throstle frame is in another respect different to the roving frame, inasmuch as it is provided with a duplicate set of drawing rollers, spindles, and flyers. Both sides of the frame are furnished alike in every respect, so it has the appearance of a double frame producing twice the power of the roving frame. The creel containing the rovings being arranged in the middle of the frame, of course the frame is wider than a roving frame, so as to provide for longer bands to drive the spindles, and to give more room for the creel to contain the extra quantity of roving bobbins. It may be asked why such an arrangement is not adopted with the roving frame as that of a throstle frame? We have seen and had frames of that kind where both sides were alike. In such cases the frames are made very short. It may be asked, again, why make them short?

In a throstle frame, when an end or thread is broken, it can be pieced, made good again, while the remaining part of the frame is working; but with the roving-frame it is altogether different. Being driven by wheels, the frame must be stopped whenever a roving is broken, so as to be able to make it good. A frame with a large number of spindles in it would of necessity be very unproductive by having so many spindles stopped during the time it requires to make good the broken roving.

Frames may resemble each other in many respects, though in other respects they may differ widely. Where such discord presents itself, we think it is desirable to enter into an explanation, and as far as possible to remove any doubt or mystery which may exist in the minds of those who are not conversant with the machines which are being described, so that those whom we are referring to may see clearly the object of certain differences. This we have all throughout this paper aimed to accomplish, and we trust that we have been somewhat successful, generally speaking.

The following description and illustration of the "throstle" will, after the practical remarks as to its working, be of service to the reader as giving him a further and clearer notion of its mechanical peculiarities.

The "throstle," which at its first introduction was called the "spinning jenny," as before stated, originally consisted of two systems, the water-spinning frame and the mule jenny. The water-spinning frame, or the throstle frame, which has now taken its place (shown in cross-section in fig. 12), is very similar to the roving frame, consisting of stretchers and spindles with spools. The machine is double—*i.e.*, it is provided on both sides with stretchers and a row of spindles. As in the flyer, the roving *a a* goes through the stretcher B, upon the front two pairs of rollers of which a roller for cleaning, covered with plush or cloth, is placed, and passes on to the spindle *b*. To

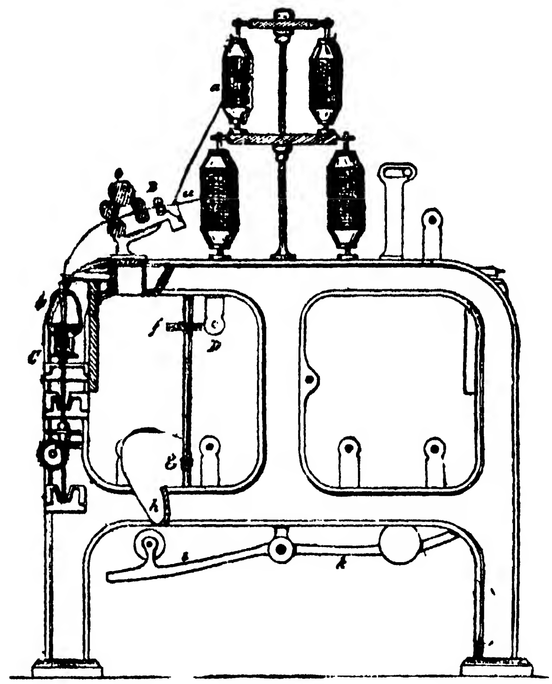


Fig. 12.

work the stretcher, the spindles, and the carriage *c*, wheels are used, as shown by the dotted lines. The wheel D conveys the motion to the wheels 1, 2, 3, and 4, those marked 5, 6, 7, 8, 9, 10 work the spindles, and the screw wheel *f* and *g*, and the heart-shaped disc *h*, together with the two-armed lever *i k*, cause the movement of the carriage *c*. The front rollers of the stretcher make 60 to 100 revolutions per minute, and the spindles 3500 to 5000. The roving receives a fourfold to tenfold stretching. On account of the firm twisting, water twist is used for crochet, knitting and sewing cotton, in preference to other sorts.

"Mule" Spinning.

The other machine used for the spinning of cotton into yarn is called the "mule,"—why, it is not easy

now to say. There was at one period a machine which very much resembled the present mule, and which was in very general use for spinning purposes, and in some districts is still in use for wool spinning, but is now becoming almost obsolete: the "jenny." It is turned by hand, and is in many respects altogether unfit for the spinning of cotton or of any other material which is made into thread. The mule partakes of many parts which are in use in the throstle frame: the creel and the drawing rollers of the mule, the twisting and the spindle, and the plan of driving the spindle. Now, seeing that it is neither "throstle" nor "jenny," it may in this way have received the name of "mule," being as it were a "cross" between the two machines. Whatever gave rise to the name "mule," it is so long since it was thus baptised, and its odd name conferred upon it, that it may be difficult to trace it to its precise origin. We are satisfied to have the name as at present understood. The mule is very different to the throstle in some of its operations, in others much the same. The produce of the mule is used for another kind of yarn: *i.e.*, the yarn being different in its finish, it is applied in a general way to other purposes than the throstle yarn. In manufacturing cotton cloth, "warp" and "weft" yarn are required. The warp being the longitudinal part of the piece, it requires much strength to bear the continual tension it is subjected to during the whole time of weaving the piece; therefore the throstle yarn is well adapted for it. The yarn used in manufacturing, called "weft," is applied to the crossing of it to the right and to the left.

This yarn is not subjected to any hardship, and it is well that such is the case, for if both the warp and weft were hard twisted, the cloth would feel like a board; but the weft being slightly twisted, it gives to a piece a "kindness" which is acceptable to the wearer. The mule is especially calculated to produce such a yarn. Hence the value of the mule yarn. The mule, as far as it partakes of the form and use of the throstle, we will now sketch out. The creel, that which carries the rovings, is of the same form as that of a throstle, where double rovings are required; the drawing rollers being in form and arrangement like those of the throstle. The twist is principally put in during the time that the rollers are running in coarse yarns. The twist is received by the revolutions of the spindles; the spindles running from seven thousand up to nine and ten thousand (too high a speed produces an unsound yarn — a little over nine thousand revolutions per minute we deem the best) revolutions per minute, and they are turned by hand and driven by a roller (cylinder) much less in diameter than the cylinder which is employed in the throstle—five to five and a half inches in diameter. The alterations of the counts and the system of changing the twists are in every respect similar to those of the throstle. The spindles, though driven in the same way, are different in shape, being much lighter and slightly tapered in the blade part,—that part which is above the bearing, and which the yarn is wound upon; no flyer being required for the mule spindle, as in the throstle spindle. The yarn is wound on the spindle; no bobbins or tubes being required for mules—*i.e.* for the yarn to be wound upon. This gives an advantage to the productions of the mule. The cops are in such a condition that they can be packed in boxes or in skips, and are thus in a position to be conveyed to any part of the United Kingdom, or on to the Continent, or may be stored for a period of time till required. The winding-on of the yarn on the spindle is performed altogether in a different way to that of the winding-on of the yarn on the throstle. That part which carries the spindles and that which drives the spindles are differently arranged. That part which carries the spindles is called the "carriage." This "carriage" is obviously well named, being a vehicle to convey. This movable carriage is so arranged that the spindles are carried backwards and forwards —*i.e.* the carriage which carries the spindles moves from the drawing rollers a little faster than the rollers turn out the yarn, so as to keep the yarn tight, or in tension. During the time the carriage is leaving the rollers (to the distance of about sixty-six inches), the spindles are running, and hence the yarn is being twisted regularly as it leaves the drawing rollers. When the carriage has arrived at its extent, and the full amount of twist given to the yarn, then the yarn which has been twisted is wound on to the spindles as the carriage returns to the drawing rollers. The spindles which are in the carriage are in a different position to those in a throstle. The position of the throstle spindles is vertical—must be as perpendicular as possible—but those in a mule must be in a slanting position, called in a spinning-mill term "bevel." This position of the spindles is absolutely necessary for mule spinning. Were they running in a perpendicular position, the threads would, as the twisting process was being carried on, snap as though they had been cut. At every twist or turn of the spindle the thread slides over the end of it, and therefore the spindle being in a bevel position, it allows the thread to slide off it,— the spindle top being almost as high as the rollers from which the yarn is delivered. The mule has from seven hundred to twelve hundred and ninety spindles in its frame; these are all drawn away by the carriage, and are returned again to the drawing rollers by the same carriage.

Most mules now made are termed self-acting— *i.e.*, they are worked by the steam engine, entirely

without the aid of any manual labour, so far as the moving parts of it are concerned. When the carriage is brought out to the full extent, and the requisite twist is added, the yarn which is wound round the bare part of the spindle is unwound by the spindles being reversed. As soon as that portion of yarn is unwound, a wire which runs from end to end of the mule presses on the yarn, and this with all its complete arrangements is called a "faller." Then the spindles are reversed again, and by this means the length of yarn is taken up. This faller is operated by machinery which causes it to rise and fall, so as not to allow all the yarn to be wound on in one place, but so as to form what is termed a cop of a tapering form. When the cops have received a certain quantity of yarn, or become a certain size, they are taken off the spindles. This process is termed in some districts "stripping," in other districts "doffing."

The machinery in connection with the mules is very elaborate. Many movements are required to be performed in order to carry the process through, in comparison to those which are needful for the working of the throstle. The motions are numerous. The drawing rollers require a separate driving—the carriage motion (called the drawing-out motion), the putting-up motion of the carriage, the backing-off motion, and the winding-on motion, each requiring a belt or wheel gearing to perform its particular work. It is remarkable with what accuracy each of the motions can be made to carry out their separate functions. Each motion, be it either by wheels or belts, must be punctual to its respective duties. We often speak about "tooth and pinion" driving, and we mean by that, generally speaking, correctness, truth, certainty of operation. The first motion in most machines is turned by a belt, excepting that of the shafting, which has mostly been made by wheels. The present mode or system of driving from the steam engine, which is now commonly adopted, is that of either "belt" or "rope" driving. Driving by wheels is very much superseded by the above plan. Belt or rope driving is cleaner and much quieter, and may not in the end cause any difference in the power. So long as belts or ropes are above the power they are intended to convey, accuracy of driving may be depended upon by them.

Mule Spinning (*continued*).

In the mule, although the first and also some of the intermediate motions are received from belts, they nevertheless have to depend upon wheels "tooth and pinion" for the precise time for which they have to operate. Wheel gearing is thus called "positive" motion, giving precise results, which belts or bands and ropes cannot do, from their tendency to slip. So long as one toothed wheel is in gearing with another, and motion is given to it, it will drive the second with a definite unchanging speed. Wheels, levers, or catches, are, so to say, the guiding reins for the belts, giving the signal to each belt, and by which the belt is removed from either fast or loose pulley. This will be, we hope, sufficient to inform even those who know but little about the actions of the various parts of the changes which have to be made with so much accuracy and precision that they may work with one another in perfect harmony. We say with perfect harmony, because nothing less will suffice. The fact of any motion, as above alluded to, being either a little too soon or a little too late, would cause confusion. As long as any movement has to depend on being driven or controlled by wheels (tooth and pinion) the same result must be continually the same. The larger the wheel (*i.e.* the more teeth there are in a wheel) the greater accuracy can be attained in the change of a wheel; as one tooth in fifty, of course, gives but one-fiftieth, whereas a wheel of half the size gives double the amount, and therefore cannot come so near to that which is required. This system of calculation is an important one, and one which is kept in mind by the machinist, as well as by those who have the charge of machinery. We have dwelt upon this system of changing at some length, with a view of satisfying those who have not had the practical advantage of examining machines, and having such things pointed out to them, showing them the necessity of that accuracy being obtained necessary to insure freedom, regularity, and order in working. We believe nothing more is needed to be said, and nothing remains to be done, except actually seeing the machine, and having each motion of it fully explained, to realise how one action is dependent upon another, so that there may be an agreement in their actions. We would recommend all our readers to take the first opportunity which presents itself to them, to examine the various machines which are treated of in this paper. In examining them it would be best to read over and over again the description given; and the reader should not be too anxious to inspect all the various machines named, but try to understand one at a time, remembering that a machine and its working cannot be understood by a single look, it being requisite to look and look again in order that the characteristics of its working and movements may be somewhat riveted on the memory. This investigation and reinvestigation is necessary to all, excepting those who are in continual practice with similar kinds of machinery; and in their case, if there be anything novel in a machine, there will not to them be more than the novel part to retain in their memory.

THE TECHNICAL POINTS CONNECTED WITH THE EMPLOYMENT OF FORM AND COLOUR IN INDUSTRIAL DECORATION.

CHAPTER V.

COLOURS which have been made to the painter as clearly existent as the evidence of his own life are denied by these uninitiated people referred to in our last chapter to have any existence at all. "Whoever," for example, "saw a green cloud in the sky?" they exclaim. Certainly they must never have seen what, if they only look intelligently and often enough, they will see—for sky lines will be seen by them as vividly green as the "grass which clothes the field." Others will be heard, in criticising a painting, to say "Whoever saw a rosy cloud like that over the surface of the sea?" Yet these, and an infinitely wider and in many instances to the popular mind more startling and incredible range of colours, tints and tones exist. And if the feeble attempts of the best of our artists to convey by their canvas what they have themselves seen, are by the great majority of people denounced as "absurd and improbable fancies," what would be said if their canvas displayed the colours as they naturally existed? In nature such colours are so intense, so brilliant, possess such a depth of tone, or what we may call life, that no colour was or will be, we may with safety say, made by all man which would or could convey even the faintest conception of the actual glory of the colour. And if the colour were ready to the hand of the artist, alas! his brush would be far from ready to put them to his canvas in such a way as to yield even some faint and feeble imitation of the loveliness he looked upon. The more nearly the picture approached what he saw in nature, the more decided the popular verdict would be, that he was just so much the better fitted to occupy a madhouse. "I am not *mad*, most noble Festus!" Alas! that no artist can complete the paraphrase, and say, "I but paint the colours of truth as they exist." For, as we have said, to no artist is given either the pigments or the power by which he could transfer to his canvas the marvellous brilliancy of scene, the depth of tint, the wonderful gradation of tone, which Nature not seldom displays to his delighted gaze. Need we wonder, then, that the public so generally and, alas! so ungenerously, ignore the "shadow" or simulacrum which at best the best artist can but give, when they resolutely close their eyes to, and will not look for, and therefore by true seeing believe in, the "substance" which Nature so lavishly provides in the colours which deck the sky, sea, and earth?

Mad! Let the pupil judge, after he has given a few weeks to the close study of what Nature actually shows him—is ready at all times to show him, although, of course, she has times and periods when she is more beautiful than at other times—when she pours down and out and around such a perfect flood of lovely colours, of infinite varieties and depths of tone and tint, that the artist can do nothing but silently gaze and drink in from the sea of beauty a full and free draught—a thirst which once created is ever being satisfied, yet still is never quenched. The pupil has not far to seek for supplies of this. If the sea, that object wonderful in all its moods, alike in that of placid calm as in that of restless storm, be denied him—and what the loss to him artistically only those who know it well can best tell—if so also the glory and the gloom of high mountain or deep dell or glen—he will most likely have some green fields to look upon. But if even these be beyond his easy reach, at least in wide expanse or in great variety of surface, it will go hard indeed if he cannot command a small stretch of green, some few hundred yards of hedgerow or fence of garden or of field, of which to study what colour it displays. And if he fancies that this will be all too narrow a field for observation, let him take but a single yard of it, and, sitting down patiently to look for such effects of light and shade upon such colour as the fence bottom, to say nothing of the stem and foliage of the quickset or thor which crowns it, looking right into the very soul, so to say, of it, with such power of concentrative observation as he may possess; then, after some time given to this, let him honestly tell us what he thinks of this his field of study, which before he thought so narrow, so "bald and bare of beauty." To say nothing of form, is it really so bare and bald in colour? Honest frankness will compel him to declare that if he could but warmly take to heart and wisely learn all the lessons which a foot or two of humble, rugged, despised roadside or garden fence or hedgerow taught him as to colour, he would be wise indeed. Some of our best artists have not had in their early days even so much as this could afford them. In narrow court or confined alley they spent their early days, and no green field gladdened their eyes. But to give a familiar illustration,—which yet teaches a truth by no means, alas! familiar to many,—like the old woman who took what she could get or had, and never lacked, so such artists took their lessons from such poor objects as lay around them; and from shade of grimy corner, or from dirty pool glinting in such scanty sunlight as could force its way between the narrow loopholes of confined alleys, they drank in more of what colour is and colour can do than other artists, with all the wide variety which travel can afford, were able to do.

And if, to the artist-pupil determined to know what colour is as painted in the pigments of nature by Nature herself, be denied almost everything which constitutes "fields" of study for its observation, if he

has the true artist spirit in him it will go hard indeed, as we have seen, if he cannot find some field which, however narrow its compass, will yield him food for study, wide opportunities for practice. But even where circumstances of life are thus unfortunate, such are now the facilities for travel, alike in speed and in moderate cost, and such, under modern social life, the time now given even to the humblest of handicraftsmen, that now and then an opportunity will be given of gazing upon wide expanses of natural beauties. From an hour or two's study of the seashore he may, under favourable circumstances, derive hints and obtain lessons in colour which may give him matter of thought and of work in his attempts to realise all he has seen; and the mere memory of the beauties of which will be solace in many a trouble, a delight for long to think over, for a "thing of beauty is a joy for ever." And what beauty there is in sea and sky let those tell—for they alone know—who have watched them for hours and days, in storm, in calm, in sunshine, and in gloom.

Such a "joy for ever" is the memory of one evening, the last of a long term of Continental travel, which the writer of these lines had the privilege to enjoy, sitting by the margin of the sea. He was accompanied by an artist—one himself an ardent lover of nature, as all true artists must be—and they were about to terminate a lengthened artistic tour amongst some of the loveliest scenery of the Continent. The whole tour might be said to be one long and ever-varied lesson in colour. They were favoured with the finest of artistic weather. The pupil will by this term understand, not that it was the finest weather in a popular sense—that is, with cloudless skies—but one which gave those changes, that play of light and shade, that alternation of cloud and bright sunshine, and all those varieties of condition which best display what artists call atmospheric effects. And in connection with the scenery they strolled and studied amongst—scenery almost, if not quite unique in beauty—the effect of weather such as this, and so long continued, was as charming in its sense of physical enjoyment as it abounded in lessons in colour and in hints and suggestions as to how to apply it in practice.

The evening we have above alluded to was one of those quiet and placid times when the air is so balmy that one feels thankful to be out, and to be permitted to breathe the open air. The sun was not far from setting, the tide was well out, and the sea itself as calm almost and placid as a land-locked lake. There was, however, just such a suspicion of a breeze that the water surface was here and there rippled into what under the sunlight might be called a shimmering sheen. This word "shimmering" is, in fact, the only one which in our language conveys a precise notion of the effect produced. The terms glinting or glancing, or the French *brillant*, may also convey the notion. A few boats of various sizes lay some at anchor, dotted here and there, others oar or sail impelled and of the pleasure kind, rowed along from time to time, giving objects which yielded striking effects in rich colour and in light and shade. The sky was a truly artistic one: here there were large masses of white-cliff-shaped clouds of the class known as cumuli. Here the sky was cloudless—there light fleecy clouds known as the cirri lay floating in the azure deep. A few of those now obscured, now opened up the sunlight. The effect of this on the water was indescribably fine. We use this term with a purpose, for our pen is not competent to give even a faint conception of the beauties we had unfolded to us as we sat and gazed. The pen even of Ruskin, the greatest word-painter, as he is in spirit amongst the truest of our artists, would fail to describe adequately what those beauties were. At the best—and our best must be of the poorest—we can only try to tell what we saw.

The tide, as we have said, was well out, so that the margin where the water, shallowing out on the flattish beach, came up to join with knife edge the ribbed sands, was at some considerable distance from us. The sun was exactly before us, and at no great height from the horizon. A change in the position of the light clouds partially—and only partially—obscuring the sunlight, opened suddenly up what may be called a lane of light, going right up to and widening—ever widening—as it reached the horizon. If any of our readers have ever had the good fortune to look into one of the re-heating furnaces used in our steel manufacture, or in working up steel into various objects, at the time when the steel masses have reached the melting point, or when their surfaces are becoming fused, they will have, and we believe they are those only who can have, any idea of the lovely white or bluish white of the surface of the "lane of light" we have just described as being opened up before us. Add to the effect of this colour that of the shimmering sheen of the surface we have also alluded to, and the pupil will have some notion of what we had before us if we describe it as a sea of molten silver burnished to the brightest, with an infinite variety of ripples in its surface, as if it were rising everywhere in boiling bubbles glistering in brilliancy. But this was not all, much as it was. Near to where the lane of light was terminated at the horizon, this plain of molten silver seemed to rise up and form a kind of swelling hill or gentle acclivity. This was crowned with a band or strip of cloud, as we may call it, of the loveliest rosy light. The way in which this changed, as if it seemed to be swayed to and fro by gentlest breeze, and the varying tint or tone thus given to the mass, was singularly striking.

THE WORKMAN AS A TECHNICAL STUDENT.

How to Study and What to Study.

CHAPTER XIV.

Common Branches of Education.—Their Close Practical Bearing on Study of Technical Subjects (*continued*).

In continuation of this important subject, we have to remark that although a course of study which bears upon one particular branch of work involves of necessity branches which concern it alone, or concern it chiefly, there are other branches which are common to all varieties of work. We do not here refer very specially to those branches which are known as common, but which are the key to all others—we mean reading and writing. We have, nevertheless, something to say on two of these more ordinary branches, specially on what constitutes the third of these branches, which have come, in consequence of a well-known bull or mistake of a public man, to be known as the ' three R's "—reading, (w)riting, and (a)rithmetic.

Some Remarks on Reading.

Before giving our brief remarks on the third of the "three R's," arithmetic, it will not be out of place here to give a remark or two on the first of them, pointing out a principle which in reality closely concerns the method of laying out the study, no matter what the branch be. Many leave what may be called the primary class or school as having been, it is said, "taught to read." And read they can, and well, if reading comprises only a knowledge of letters and words, and a capacity either to pronounce audibly or to comprehend readily the collocation of those making up the sentences and the words of written or printed language. But reading means something more than a facility readily to comprehend what the letters mean as regards the mere formation of words, so that the comprehension may be said to come intuitively, and as it were at a mere glance. It means that this mere mechanical facility, so to term it for lack of a better expression, carries with it also a capability of comprehending what the combination of letters, words, and sentences means, making up the arrangement or matter of the written or printed language. If reading means this (and surely if it does not it has no practical meaning or utility at all), we fear that many have got into such a slipshod style, so to call it, of reading, that they can scarcely lay claim to the title of good, that is, intelligent, readers. The question, "*Understandest* thou what thou readest?" put long ago on the plains of Syria, might be put to many, and, if honestly answered, the reply would be in the negative. It might not, or indeed it generally is not, that readers have not natural capacity to understand if they will do so; it is the carelessness to exercise the will; they are generally content with the fact that they have read, if they conceive it a duty to read at all,—a duty which a vastly larger number do not fulfil than some might at first be disposed to admit. These last belong to the class of whom it might be said "they never have a book in their hands."

Dangers of Desultory, Careless Reading.

But be this as it may, the fact nevertheless remains that many do read who, when the above point is considered, practically are but little better off for anything they have learned from their reading than those who have not, nor seem to care whether they have or not, the reputation of being readers. In brief, to be able to read, to use the only phrase permissible here, is one thing, to understand quite another. Even the most careful of readers, anxious in all honest dealing with the author to understand what he says, often find themselves so dreaming that, though their eye takes in the letters and the collocation of words or sentences, the mind has gathered up none of the sense, so that they have to return to master the meaning of that which they have been in point of fact looking at only—that is,

Reading Mechanically,

so to say. A very fair test, and an easy one, within the reach of all readers and in the most of writings, is involved in this. Suppose one is reading a part of a work in which the author is asserting a certain principle, and therefore illustrating his enunciation of it by various examples, and enforcing it by certain considerations. He begins a new paragraph by such an expression as this: "Now, these considerations are of the utmost importance to be borne in mind; for they forcibly illustrate the value of the principle we have endeavoured to explain." At this point we can suppose the reader to halt and, so to say, pull himself up with the questions, What *are* these considerations? what is this principle the author here refers to? Will the reader be surprised if we say that if this test were so put by very many ordinary readers, we avow our belief that a large majority of them would—giving a thoroughly honest answer to these questions—have to admit that they could not give an off-hand *vivâ-voce* account of what the considerations illustrating the principle are—were still less able to go so far back in the recollection of what they had read as to state what was the principle itself? Even most careful readers, who are determined to understand what they read, do find themselves at times in such a position that such a test as we have indicated would fail to be satisfactorily passed. And it must be confessed that reading such as this is not true reading, the very object of which is to understand what is being read. And the importance will surely be readily admitted of so cultivating a style or system of reading, that an intelligent grasp will be obtained of the meaning of the author. It is not how much a man reads that is the gauge of his study, but how much he understands of what he does read. Better that a student should

only read one page a day, knowing what he has read, making it his very own which he can carry about with him wherever he goes, and draw to his help whenever he requires it, than read a volume, of which, after its perusal, all that he can truly say of its contents is that he has of them but the vaguest of notions; of which, therefore, practically he only knows this—namely, that he knows nothing.

It will help much to get rid of this purposeless kind of reading, which is but reading only in name, if the student, after reading a certain portion, sits down to put into his own language in writing what he thinks the author has said. Failing the writing, if he has nerve and honesty of determination of purpose enough, he may try to repeat *vivâ voce* his impression of the author's meaning. If this is done the honest reader has every reason to congratulate himself on the fact that he is quick in apprehension, and has a retentive memory, if he is able always after reading a page or two to be able to say that he knows pretty fully what occupied these pages—facts as well as reasoning. How many honest readers, on the contrary, will have to confess that in too many instances they have almost completely forgotten the facts to which the author in one page alludes as having been stated by him in perhaps the very last page passed over. As we have already stated, reading with a result like this is but reading in name. And nominal reading, such as this, had almost better be let alone, and not gone into at all. Almost the only value it possesses is a negative one—that is, that while one is engaged with it he is at least doing something which may ultimately tend to the love of reading, and of reading with thought; and that it at the least prevents positive idleness, which, as a great writer says, "is the very canker and rust of life." Better, therefore, to be doing something which, if not useful, is at least harmless. But this is taking far too lenient a view of this habit of careless reading. If it possesses a negative value, it, on the other hand, carries with it a positive evil. It exercises, in truth, a pernicious influence on the mental faculties. It has been said in its favour that it *may* ultimately lead to a habit of careful reading—that is, reading with thought. All that we can say in favour of this view is that it "may." There is, however, in the great majority of instances, the much greater likelihood that the "may" will be supplanted by the "will not." Like all bad habits, the great probability, nay, the almost absolute certainty, is, that the longer it is practised, the stronger will its influence become, till at last it may be confirmed. And what the evils are of any confirmed bad habit, no matter what it be, we surely do not require to remind even the youngest and least experienced in life of our readers Let us urge, therefore, on the reader who may be fast getting into this habit of reading without thought, to make an earnest effort to get rid of it. And he will find this task, difficult as it may at first be—and it is wise discipline to become acquainted with the fact that we have difficulties to encounter—that the longer he perseveres in overcoming the evils of this pernicious habit the easier the task will be. Each step in his advance in a truer and nobler—noblei because true—path will bring with it a mental satisfaction which no amount of idle and easy gratification can ever give.

Value of a Habit of Careful, Thoughtful Reading in General in Relation to Technical Subjects.

Nor let it for a moment be supposed that this habit of careful, thoughtful reading is one the value of which is confined to this department of education only. We would desire to impress upon the minds of all students, with all the earnestness which a sense of the high importance of the subject gives us, this truth—that the good habit we are insisting upon has a direct and individual influence of the most valuable character upon all branches of study to which attention may be directed. We have written to little purpose if we have not shown to the clear comprehension of even the most youthful of those who peruse these pages with some practical purpose in view, that "reading" is an art, and, like all other arts, deserves, and indeed demands, if the art is to be acquired, all the carefulness and precision of earnest-minded study. Let it ever be remembered that reading is not the merely mechanical faculty to put letters together to form words, and words sentences, which, unfortunately, too many seem to think it is. It is, as we have shown, something vastly more than this. It is the key to all knowledge, the very base or foundation on which rests the method of acquiring knowledge of all kinds. And we do not require to tell the student what a worthless thing any structure is which is placed upon a bad or totally insecure foundation. How a careless, thoughtless reader is to become a careful, thoughtful student of any branch of knowledge he may attempt to study, and to which reading must be the key to unlock its treasures, we confess to having a difficulty to see.

Primary Education, as Reading and Arithmetic, Technical in Character.

The truth of what we have advanced will be seen at every step taken in acquiring a knowledge of those branches of study which are purely technical. It is seen also in the study of that branch of education which, like reading, is unfortunately too much and too frequently considered to be only one of the ordinary branches of preliminary education, which may be carried on without that current attention which some attach only to what are called the higher branches, such as those of technical studies. We refer

here to the third of the "three R's," namely, *arithmetic*: about which we have stated that we had somewhat to say. And how closely it affects the course of technical study to which the reader is assumed to be devoting his attention, will, we trust, be clearly seen. It is unfortunately the case, in what may be called the every-day life of teachers and taught, that very loose notions prevail but with too many of those concerned in its actual work, as to the value of the ordinary branches of education. The very phrase "*mere* reading, writing, and casting up accounts," so often used, indicates this feeling. The fact is overlooked that, rightly computed, they are the only basis upon which the acquirement of *all* knowledge rests. The talk is common enough of primary education, as it is called, and technical education, as if they were two quite distinct things, having nothing in common, and to be pursued by totally different methods. If primary education be not technical in the fullest sense of the term, we utterly fail to see what it is. If the art of reading, the science of arithmetic—we use the terms as they are commonly applied—be not pursued in the same way as every branch of technical study should and must be, if knowledge of it be desired,—then we venture to say that what one does know of reading or of arithmetic is purely mechanical, so to say—what a parrot might in course of time be taught just as well. A teacher so called, who, in teaching a boy to read, merely enables him to acquire a knowledge of how letters form words, and words sentences, without taking care to see that he knows—absolutely knows—what the meaning is of the words and sentences he reads, has only taught his pupil to pronounce—possibly not even that in the sense of correct pronunciation. Harsh as this judgment may appear to be, it is simply literally true. Hundreds—we should not be far wrong if we said thousands—of boys leave school, who are said to have been taught reading; the only thing they have really learned being the capacity to give vocal utterance to printed or written signs, signs which convey absolutely nothing to their minds so far as the intellect is concerned. If any reader doubts the truth of this statement, let him make honest and patient inquiry—and patience will assuredly be demanded of him—for himself into the matter, and he will endorse what we have said, and agree with us as to the full importance of all that our statement involves.

Education Proper is not what is called popularly "Learning."

We know those who had their school or, as it is now called, primary education—too often without a thought of what this term involves—conducted by men who ranked as "first-class teachers," but who never once had pointed out to them what truly constituted the value, the vital point cf reading. They read and read, and, as the teacher very likely said, with accuracy; understand what they did read they might, or might not. But so far as the teacher knew this he might as well have been absent. Nay, to not one of the pupils was even the faintest gleaming of the truth shown that the only object—and there is no other that is true—of reading, the only value existing in the capability to pronounce, either audibly or inaudibly, written or printed signs, is to convey to the mind of the reader what intellectual truths and facts the signs are intended to convey.

Defective Primary Education—Its Important Influence on Technical Study—Arithmetic.

The same pernicious system but too often runs through all the branches of primary or school education. Rules of grammar are "learned," as the phrase is, but they are not "taught," if teaching is to be interpreted truly. With unfailing accuracy page after page of "rules" and "examples" are set forth, but not the slightest conception rests in the pupil's mind as to what the true connection is between the rule and the examples; nay, he is not even told what the meaning of a "rule" (or law) is. Put the rule at the beginning of his book, and the examples at the end of it, and give thus a long interval between what is called the "learning by heart" of both, and he will be neither wiser nor worse than before; for on the system on which he is said to be taught he has not the remotest intellectual conception of the true connection between the rule and the example. The same holds true of all the branches of school or primary education. And in none is the evil influence of the principle—if it be worthy of the designation in its best and highest meaning—more observable than in arithmetic. Here no true knowledge of the science can be imputed unless the pupil knows the "reason why" a certain operation is done. And let it be remembered that this science is not one which gives merely a capability to cast up accounts to know something of pounds, shillings, and pence. For the idea connected with this branch of education goes with a great number not any higher than this. Arithmetic is the basis of even the highest science the work of which is mental—namely, mathematics. Without the simple rules and operations based upon these rules the mathematician would seek in vain for a solution of the highest of his calculations. And how far in the course of ordinary or primary education the pupils are taught to know the reason why certain operations are performed, or how the "examples" which they do with such accuracy depend upon, or have a real connection with, the "rules," let those say who know what ordinary school teaching is, and what the condition is of a very great number of pupils as they leave school, said to have a knowledge of arithmetic.

THE FARMER AS A TECHNICAL WORKMAN.

His Tools, Implements, Machines and Materials. —The Principles of his Work in its Various Departments.

CHAPTER X.

Even the slight acquaintance with soils we have above assumed will suffice to show that their mechanical features, as they have been called—that is, their physical condition—vary very much: that while some are hard, dense, and close, others are more open, and what is termed porous. Taking this as a whole, we find in fact that they range from the densest clay to the lightest sand. All, however, have this peculiarity: that under the ordinary atmospheric influences of air, rain, and frost, the lumps or masses or nodules or particles of varying size, hardness and closeness, have a tendency to go closer together and to get levelled down and consolidated, or in common and what may indeed be called technical language, to "settle down." A very familiar illustration of this may be obtained in a common garden, or upon any small patch of ground open to the experimenter. For if a certain space be dug over deeply, and the soil well turned over, say in the autumnal part of the year, being left rough and uneven on the surface, and with lumps or masses of greater or less dimensions,—if allowed to lie thus exposed to atmospheric influences, as named above, and examined in the late spring of the following year, it will be found that many of the lumps or masses have disappeared, the rough surface has got smoother or more uniform in level, and where the atmospheric influences have been active, the general level of the whole lower than before. If the experiment be continued, or rather extended over a longer period, say for several seasons, it will be observed that with each succeeding season the general surface becomes more level and uniform, and the raised-up condition caused by the lifting up and turning over of the soil gradually disappears and the general level becomes lower and lower. This subsidence of the general mass obviously causes the whole to be consolidated. For if on first digging the soil the part under the surface could have been examined, it would have been found that there were open spaces formed by the contiguity of lumps or masses of particles of unequal form. But after a while, with the alteration in the condition of the upper or visible surface such as we have described above, if the under surface could be examined those open spaces would either be fewer in number or less in capacity or size, and in some cases quite done away with, the whole forming one solid or homogeneous condition.

If this experiment were continued over a sufficiently wide variety of soils, it would be seen that with the different classes there would be a difference in this tendency to become levelled in surface, to subside and consolidate. Some would show this in a very short time, others would resist it much longer; while some would display it so feebly as to have their visible condition very little altered, even after a long season and a marked exertion of atmospheric influences. But this tendency of the particles of soil to subside and consolidate involves the opposite or converse—namely, the tendency to be divided or broken up. On first turning over the soil in our supposed experiment, the condition of the surface as to roughness or unevenness would be found to vary with different soils. And this roughness would obviously depend upon the size or bulk of the lumps, clods, masses or nodules of soil. In some soils these masses or lumps would be large, in others small. And if the experimenter were a man of observation, he would at once see that the size was dependent upon the physical quality of the soil; the denser and closer soils forming the largest lumps, the more porous or open the smallest—some being so loose and open that the lumps would be few and small, while in others they would not be present at all. Further, if at the time of this turning over the soil those lumps were struck by the spade, or attempted tc be crushed or broken up by the foot or hand, it would be found that while some would break up with the slightest blow or touch, so to say, others would resist stronger blows for a longer time; while others would, in place of breaking up under the force of blows, only become all the closer and denser. But if this trial of breaking up of some of the clods or lumps were delayed till the spring following the autumn of experiment, it would be found that the breaking up of each individual mass or lump would be much easier done in the same quality of soil than was done the autumn before; while some lumps would be found to have disappeared altogether—merging, so to say, into the general mass. Even those which were the most obdurate would be found to be more amenable to the breaking-up process. And if observation were made, this tendency to break up into separate particles would appear to be very much influenced by the season—a winter of hard frosts, with cold thaws attending, giving the most noticeable results; the expansion consequent upon the freezing of the particles of water or moisture lying between the particles of the soil in the lumps causing their disruption or forcing asunder. The tendency of rains is to wash out and carry down the particles of soil from a higher to a lower level, and this also tends to consolidate in proportion the general mass.

Many of the facts we have here named may be illustrated and exemplified on a smaller scale by those fond of the cultivation of flowers in pots; for if observant they must have seen how the soil, at first light and loose and quite reaching up to the level of the rim or edge of the pot, gradually sinks lower and

lower and becomes harder and closer in the body of the pot; while particles of soil washed out, so to say, will be found lying in the saucer if the pot be lifted up for examination. But if consolidation of the particles lessens the bulk of a mass of soil, stirring or moving and breaking of it up ncreases it. A very suggestive lesson can be learned in connection with this, from the practice of flower cultivation in pots. Take the soil out of the pot which has got in process of time so consolidated as to be considerably below the level of the edge or lip of the pot, and break it up by hand, so that it becomes loose and open, or, as the common phrase has it, pulverised. Replace the soil thus treated in the same pot: you will find, in fact, that you cannot actually replace it, for there is now more soil than is required to fill it—that is, if put in so as to fill or take its place naturally. To get all the pulverised, broken up soil into the same pot you must press it in and down. There is no more soil than before; you have only increased its bulk, not altered its weight or in any way that of its chemical constituents. And the excess of soil over and above that you can get in the pot if allowed to take its place naturally, is simply the measure of the degree to which you have opened up or loosened the particles. On first beginning to replace the soil in the pot a handful or two appears to fill it; but you have only to shake the pot, when the mass is lowered in its surface, and more space is given to receive fresh soil. By the shaking you have lessened the spaces between the particles and in proportion consolidated the soil. The same result of opening or breaking up of the soil is observable on a larger scale if a trench or hole be dug in the ground, and the soil or "earth" be thrown aside as it is dug out: if you throw this loosely into the trench or hole you have made, so that it falls and deposits itself naturally, you will find that you cannot get in all the soil you dug out of it. There is a very considerable surplus, which may be taken as measuring the extent to which the soil has been opened up.

Returning to the experiment with the flower-pot, a very important lesson in connection with soil may be learned from it. If the flower or plant which has been growing in the pot be taken out along with the soil, and the latter be carefully broken up so that the roots are gently exposed without much disturbance, it will be interesting to trace how they have penetrated into and through and amongst the particles of soil. On examination it will be seen that the natural tendency of the roots is to grow or extend downwards or vertically, while the rootlets (the distinction between these two terms will be noted in a succeeding chapter) will have a tendency to shoot out and spread themselves laterally. If the flower-pot be small, and the plant permitted to grow a long time in it, the rootlets will have so multiplied and extended themselves that the mass of soil seems quite filled with them, and they extend even to the outer surface and have formed a kind of network between it and the flower-pot. So numerous are they that they bind the soil together, making it so solid a mass that the flower, soil and roots can be lifted bodily up and the whole taken up without disturbing it or the flower. A plant in this condition becomes stunted in its growth, simply because there is not room enough in the pot for its root development, nor soil enough to nourish them. And in order to enable the plant to grow and increase in vitality it has to be re-potted or moved into a larger pot filled with fresher soil. If all this work be done with intelligent observation, it will be seen that the harder and more dense the soil, the more difficulty the roots will have to penetrate it, and the fine delicate rootlets to spread themselves according to the manner of their natural growth or development. For just as we find that each kind of fruit or forest tree and each shrub follows, as it were, its own law of branch ramification, so each plant has its own law of root development. What this is in relation to the principal farm crops we shall see as we proceed.

We have thus gone somewhat minutely into what may be called the phenomena of soil and plant root relation, as it is of essential importance that the reader should from the outset have an intelligent understanding of them. For on those points rests the whole practice of preparation of the soil for the reception of crops and of the after cultivation of them.

Practical Points connected with Soils.

The soil is the most important factor in all the calculations to be made in connection with crops and cropping—that is, the cultivation and after treatment—and it is to a due understanding of what soils are and the direct relation they bear to the crops and to the manures which are added to it, that we look for the advanced progress above alluded to. But under the general heads of Soils and Manures there fall to be considered a number of subjects, each of which has a special function or duty to perform, but yet the whole have a clear and distinct relation to each other and to the soil,—so much so that unless they be taken into account, we are sure to draw erroneous conclusions as to what the effect produced in any particular kind or form of soil preparation or culture. There is again a close relationship existing between the condition of the soil and the crops which are grown upon it, and also in the way in which different crops, which are what may be called the movable or changeable factors, are made to occupy the soil, which is the fixed or permanent factor in all our calculations as to cropping. Further, there is a distinct relationship between the soil on the one hand

and the crops on the other, and the manures which are supplied to the soil in order to increase the products of the crops. Taking, then, the soil as a centre, we have clustering and revolving, so to say, around it, other factors, all of which have to be considered as separate agencies, although, as we have said, they all act in conjunction or in unison, tending to bring about the ultimate result in the crops obtained from the soil.

And here is the fitting place to point out to the reader the importance of the consideration to which in a previous chapter we have alluded, in relation to the subjects now about to be discussed in connection with the soil. For although we shall find that in the theories more or less widely accepted in connection with the soil there is a certain amount of definite precision, still in practice there is a variety of circumstances which go to modify very materially the indications of theory. Those circumstances we have already dwelt somewhat fully upon, so that all that is here necessary is merely to name them, those being the peculiarities of the locality and climate, and perhaps still more markedly of the soil itself, in which there may be and as a rule generally are present substances which act more or less powerfully, and in a way which, while we may reasonably guess it, is in reality in all its circumstances unknown to us. In every calculation we must have all the factors before we can arrive at the final result or product. But having the factors, we can predicate with absolute certainty that we shall obtain a result which may be relied upon. Now, in all agricultural processes connected with cropping we have not this certainty, simply because we do not possess all the factors. And, considering the mass of soil with which we have to deal, and the practical impossibility of knowing what is present in it, and what moreover are the combinations taking place within it, of which the circumstances are and must be unknown to us, and further, knowing so little comparatively of the real life of plants, and of many points connected with their assimilation of fertilising constituents, and how the soil acts and reacts upon them, the reader will now perceive how it is that there is such a diversity of practice in farming, and further, how the diversity in results is made, or is likely to be made, all the more marked and puzzling from the influences of locality and specially of climate, the latter being an influence over which we have no control, powerful as that influence is.

In becoming thus acquainted for the first time with the theories or the science of farming in relation to the soil and its kindred or connected subjects, and with which we have presently to deal, the reader must carefully guard against receiving the impression that the theories can be applied to or are capable of giving definite results in practice which can be relied upon as invariable. Science has done much for farming, and it is daily proving that it will do more; but like all true science, which never assumes, but deals with only facts, it does not claim for itself the position of an unerring guide, saying to the practical man, Do this, and certain results will follow with absolute precision. On the contrary, agricultural science tells the practical man that it can only indicate the leading points, and faithfully warns him that while it claims to do much for him, it cannot do all. But this comparative degree of scientific knowledge has been of immense advantage to the farmer, and will yet be more so, the more it is applied. It possesses this great value—that, while it cannot always tell the farmer what to do, or rather what will be the probable results of his doing, it tells him in no uncertain language what not to do. And the lesson of what to avoid is frequently as valuable as the lesson of what to aim at. The reader will now be prepared to see the reason why there is such a diversity in the practice of the farmer, and why also there are coming up continually points which cause also a diversity in scientific opinion,—for farming is in no way free from the peculiarity which characterises other branches of industrial work, in that the conclusions of some men of science are keenly disputed as to their value and accuracy by others.

Classification of Soils.

Soils are roughly divided into three classes—the heavy, the medium, and the light; and these again are known generally as clay, loamy and sandy, or chalky soils. In each division there are sub-classes or varieties, forming a scale as it were of different gradations. But there is one peculiarity connected with soils which must not be overlooked by the reader. While there are some districts and localities marked for the preponderance of a certain class of soil, as for example, the well-known London clay lands, or the light sandy soils of a district on the coast of Lancashire, it must not be supposed that each class of soil is marked off from another class by certain well defined and easily recognised lines. That the contrary is frequently the case, those of our readers who are acquainted with geology know well enough. And just as we find that in each class of soil, such as heavy or clay, or light or sandy soil, as the case may be, there are different degrees of heaviness or lightness in the same soil or mass of soil, so do we find that there is in some instances a toning down, say of a heavy soil, so gradually done that it is difficult to say where the line is which separates a light from a heavy soil, or *vice versâ*.

THE GEOMETRICAL DRAUGHTSMAN.

HIS WORK IN THE CONSTRUCTION OF THE FIGURES AND PROBLEMS OF PLANE GEOMETRY, USEFUL IN TECHNICAL WORK.

CHAPTER XVII.

In the last paragraph of preceding chapter (p. 48) we named the different classes of curves. Of the last named but one of these, the epicycloid, there are two classes —first the "external" and secondly the "internal." To the problems or constructions connected with the curvilineal figure, strictly so called—the "ellipse," and to the curves or curved lines the "parabola" and the "hyperbola," and those other curves named, and which are frequently classed as being amongst the "higher curves," the "cycloid," "epicycloid," and the "involute," we now direct the attention of the reader. All those figures (to use the term so frequently applied to geometrical constructions) are in their practical application to the constructive arts of the greatest service to the engineer, the architect, and all the trades engaged in what are called the constructive and building arts, as the machinist, the carpenter, the builder, etc., etc. Those more direct and practical applications of the curves we have named will form part of the series of papers given in this work under the title of "The Building and Machine Draughtsman." What we have now to concern ourselves with are the general problems connected with them, which fall more legitimately within the limits of the present series of chapters. The first of the curvilineal figures or curves we take up is the ellipse: this may be popularly defined as a species of flattened circle; it may thus vary in form from the full circle to its complete flattening, which then becomes a straight line. This popular definition may be illustrated by supposing the draughtsman to take a globe or sphere, which, looked at in elevation (for this term see the paper "The Building and Machine Draughtsman"), appears to be a circle. This globe or sphere we suppose to be made of a soft material, possessed of a certain degree of elasticity and consistency. This being placed upon a flat surface, may be considered as being pressed upon by the palm of the hand. The pressure causes the globe or sphere to change its shape—being depressed in the centre and widening out to the right and left. Its length is now greater than its height, and the new shape when looked at in elevation is what is called an ellipse, or popularly an oval. By continuing the flattening or pressing process one may conceive of the globe being so pressed down that it becomes merely a flat circle as looked down upon in plan, but assumes in elevation the appearance of a line. In a circle we may say that the length is equal to the width, for two diameters intersecting perpendicularly are equal. In considering these two diameters as axes, we see that in the ellipse the axes are of different extent, the greater measuring the length, the shorter the width. The ellipse, then, will be more elongated in proportion as the distance between the axes is greater, and the less the two axes differ the nearer will it approach the form of a circle. The point of intersection of the two axes is called the centre of the ellipse; and the axes of the ellipse are the longest and the shortest straight lines that we can draw in its interior through the centre. The "ellipse" (or "oval," as it is popularly, but as we shall presently see, erroneously called) is a continuous curve, which, although circular in appearance, as in fig. 96, has no portion of it that of a true circle. Like the circle, however, it is a continuous line running into itself, and thus inclosing a space; so that, as we have said, it is entitled to be classed as a figure—meaning by this a form which incloses or forms a surface or superficies. This continuous curved line is generated by a line having relation to two points called "foci," as *c*, *d*, each one being singly termed a "focus." The shortest diameter, as the line *e f*, continued till it touches the

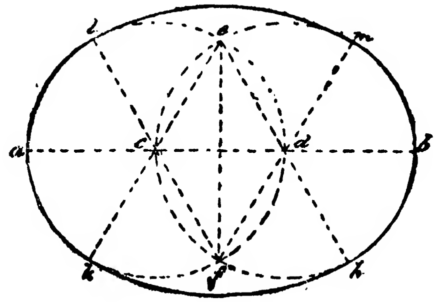


Fig. 96.

curve, is called the "conjugate diameter" or "minor axis," this being situated midway between the two foci, *c* and *d*, and at right angles to a line, as *a b*, which passes through both foci and is terminated by the curves at each end, as at *a b*.

The longest line, *a d*, is called the "transverse diameter" or "major axis." All lines which are bisected by a diameter, or axis, as the line 1 2, fig. 2, Plate CCXVIII., by the diameter *a b*, are called "ordinates" to that diameter; the part, as 1 *a* 2, where the ordinate, as 1 2, touches the curve *m d n* of the ellipse, is called the "vertex" of the ordinate. When an ordinate, as 1 2, cuts the transverse diameter *a b* into two parts, as in the point 3, the parts, as *a* 3, 3 *b*, are called abscissa. The point *h*, where the shortest or "conjugate" diameter *c d* intersects the longest or "transverse" diameter *a b*, is called the "centre" of the ellipse. The draughtsman, however, should not associate this in any way with the centre of a circle, the curve of which is generated round a fixed point called the "centre," and is equi-

distant at all points from that point. In the ellipse the curve is continually changing its direction, and there is no one point or centre within the curve of an ellipse from which any two points in that curve are equidistant. The true method, then, of finding the outline of an ellipse is to find a number of points in the true line of the curve, through which points a curved line is drawn, which gives the outline of the curve.

There are also methods of mechanically describing the curve of a true ellipse by means of an instrument called the elliptograph, of which there are various kinds, and on the large scale by means of a cord and pins or stakes. Solid bodies possessing in their outline the true curve of an ellipse can also be made by cutting certain solids in certain directions; as, for example, the cone (hence the term conic sections—a useful but difficult branch of geometry, to which reference will be practically made in the papers entitled "The Building and Machine Draughtsman").

Although an ellipse, considered as a figure inclosing a space, has, as we have said above, no part of its curve forming that of a true circle, still there are several methods by which, with the junction of arcs of circles, outlines may be obtained which *approximate* so closely to the curve of a true ellipse, that for many practical purposes they are sufficiently correct. The best of these methods we shall give as we proceed. As we have already stated, the true curve of an ellipse is that of a surface produced by sections or cuttings of the two solids, the cylinder and the cone, by lines which are oblique to their bases. Thus, if a cylinder is cut by a line parallel to its base, the section will have the outline of a true circle, the diameter of which will be equal to that of the cylinder. And as the cylinder has parallel sides, all sections at any number of points in its height, and all taken by lines parallel to its base, will be circles of the same diameter. But if the cutting line of the section be oblique to the base of the cylinder, then the surfaces produced will have curved outlines which will be ellipses, the length of the transverse or longest diameter being equal to the length of the cutting oblique line, of the shortest equal to the breadth of the cylinder at the widest part of the cylinder section. In the cone all sections taken through lines parallel to the base will be circles; but as the sides of the cone are sloping, and are continually changing their distance from the central line, no two circles can be obtained of the same diameter, as in the case of the cylinder. But if the cutting line of section be oblique to the base, the surface produced will have a curved outline, which will be that of a true ellipse. The application of the principle—here generally described—of the section of solids in relation to the ellipse to many of the practical constructions of the architect and engineer, will be found described and illustrated in the series of papers in this work given under the title of "The Building and Machine Draughtsman.'

What we may call the conventional or ordinary method of producing the curve of an ellipse is by using arcs of circles, the centres of which are found in different ways more or less complicated. The curves thus obtained, from what we have said above, will be seen to give curved lines merely approximate to the true curve; still, for many purposes, they will be found sufficiently correct; we therefore here proceed to give a few of the methods based upon this system.

To describe an Ellipse or Oval by means of Arcs of Circles.

Having drawn, as in fig. 96, a straight line, *a b*, forming the transverse diameter or major axis of the ellipse, divide it into three equal parts, *a c*, *c d*, *d b*; from the points *c* and *d* as centre, and with the radius *a c*, describe two circles which will intersect at *e* and *f*; from these two last points as centres, and with a radius equal to *f m*, describe the two arcs *m l* and *h k*, which, in uniting with the arcs *k a m* and *l b h*, will form the ellipse required.

To describe by means of arcs of circles an elliptical curve further removed from the outline of a circle than the curve described in last paragraph. Describe, in the first place, two equal circles, fig. 7, Plate CCXV., and join their centres, *a* and *b*, by a straight line which forms the major axis or transverse diameter of the ellipse. From the points *a* and *b*, and with the distance *a b*, determine the points of intersection *d* and *e*; from these points as centres, and with a radius *e c*, terminate the ellipse by drawing the arcs *i f* and *g h*, joining the arcs described from parts *a* and *b*. The line *i j* is called the minor axis or "conjugate diameter," and the points *a* and *b* the foci of the ellipse. It is not necessary to make the two circles touch each other, as in this figure: we can make the ellipse more elongated in proportion as the centres *a* and *b* of the two circles are farther apart from one another, and *vice versâ*.

In fig. 1, Plate CCXVIII. we illustrate another method of describing an elliptical curve by means of arcs of circles, in which the lengths of the two diameters are given; in the last two problems or constructions the two diameters have not been given or determined, only the transverse diameters or minor axes, as *j i*, fig. 7, Plate CCXV. In fig. 2, Plate CCXVIII., the two are determined, the conjugate *c d* as well as the transverse *a b*, the conjugate being larger than half of the transverse. Let *a b* be the given transverse diameter, or "major axis," *c d* the conjugate, or "minor axis." Take *c d* in the compasses, and set it off from the point *a* to *e*; divide *e b* into three equal parts in the points *f* and *g*. With the distance of two of these, as *e g*, from the point *h*,

where the two diameters intersect, set off to the points *i* and *j*. From *i* and *j* as centres, with *i j* as radius, describe arcs cutting in the points *k* and *l*. Through the points *k*, *j*, and *i*, draw lines cutting circles described from points *i* and *j* as centres, with radii *i a*, *j b*, in the points *m* and *n*. From the points *l* and *k* as centres, with *l n*, *k m* as radii, describe arcs *m o*, *p n*.

To describe an Oval or Ellipse within a Rectangle by Arcs of Circles.

It may sometimes be required to describe an elliptically shaped curved line, or what we popularly call an oval, round a circumscribing rectangle, as *a b c d*, fig. 4, Plate CCXVIII., the length of which will be twice that of the breadth, or, in other words, round two squares. In this case describe the squares *a b f e*, *e f c d*, then draw the diagonals, as *g* and *h*, as centres, and distances as *d g* as radii, describe arcs of circles as *i* and *j*.

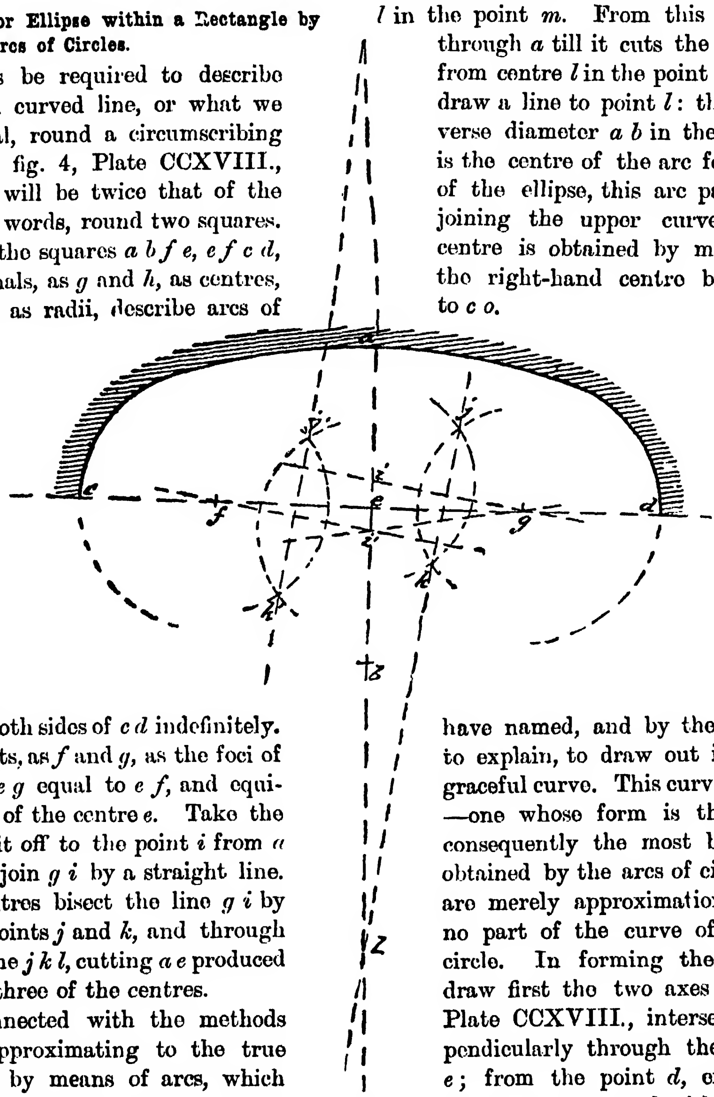


Fig. 97.

In fig. 97 we give another method of finding the centres of arcs which will give a curved line approximating to that of the true ellipse. In this let *a b* be the conjugate and *c d* the transverse diameters, intersecting in the point *e*; continue *e a*, *e b*, on both sides of *c d* indefinitely. Assume any two points, as *f* and *g*, as the foci of the ellipse, making *e g* equal to *e f*, and equidistant on both sides of the centre *e*. Take the distance *c f*, and set it off to the point *i* from *a* on the line *a e*, and join *g i* by a straight line. From *g* and *i* as centres bisect the line *g i* by arcs cutting in the points *j* and *k*, and through those points draw a line *j k l*, cutting *a e* produced in *l*: *l*, *g*, and *f*, are three of the centres.

The problems connected with the methods of finding curves approximating to the true curve of the ellipse by means of arcs, which are useful in the ordinary practice of the draughtsman, are not yet exhausted. We give another method in fig. 7, Plate CCXVIII.

Let *a b*, *c d*, be the distance of the two diameters intersecting at *c*, to find the curve. From point *c* as a centre, with *c d* as a radius, describe an arc *d h f*. From *c* describe also an arc, as *a g*, with radius *c a*. With the set-square of 45° bisect the arc *d f* in the point *h*, and from *c* draw through this point the line *c h*, cutting the arc *a g* in the point *i*. From *h*, parallel to *a b*, draw a line *h j*, cutting one dropped from the point *i*, the two cutting in *j*. Produce *d c e* indefinitely, join *d j*, bisect it by arcs described from *d* and *j*, cutting in the points *g* and *k*. Through *g* and *k* draw a line bisecting *d j*, and produce it till it cuts the line *d c e*, produced in the point *l*. The point *j* is in the curve required. The upper part of the curve is described from the centre *l*, with radius *l d*. Continue this till it cuts a line drawn parallel to *a b*, from *l* in the point *m*. From this point *m* draw a line through *a* till it cuts the curved line described from centre *l* in the point *n*. From this point *n* draw a line to point *l*: this will cut the transverse diameter *a b* in the point *o*. This point is the centre of the arc forming the end curve of the ellipse, this arc passing through *a* and joining the upper curve. The lower curve centre is obtained by making *c q* equal to *c l*, the right-hand centre by making *c p* equal to *c o*.

Of the Gardeners' Ellipse.

An ellipse on the large scale may be described by means of a cord and pins or stakes; the curve thus obtained is usually called "the gardener's ellipse or oval," inasmuch as these workmen frequently make use of the appliances we have named, and by the method we are about to explain, to draw out in flower gardens this graceful curve. This curve gives the true ellipse, —one whose form is the most regular, and consequently the most beautiful. The curves obtained by the arcs of circles already described are merely approximations to the true ellipse, no part of the curve of which is part of a circle. In forming the "gardeners' ellipse" draw first the two axes *a b* and *c d*, fig. 3, Plate CCXVIII., intersecting each other perpendicularly through the middle at the point *e*; from the point *d*, extremity of the small axis, as centre, and with a radius equal to the half of the large axis, describe an arc which will cut this large axis at the points *f* and *g*; these two points will be what are called in an ellipse the foci. Take a cord or string of twice the length *a g*, and fasten it at two fixed points on the points *f*, *g*, which are the foci, so as to form with the point of the pin or stake *h* a triangle *f g h*. The pin is embraced by the fold *h* of the cord, and care should be taken that the latter is equally stretched during the whole operation.

THE BUILDING AND THE MACHINE DRAUGHTSMAN.

CHAPTER XXIV.

The "Archimedian" spiral is illustrated in fig. 44. Draw any number of lines, making equal angles with each other, and all intersecting in a common point, as *i*. Suppose there are to be five turns in the spiral, divide half the height of the spiral, as *i c*, into five equal parts, and divide each part, as *c k* shown in large scale in diagram A, into the same number of equal parts off to the point *m*, the second part to *n*, and so on, thus finding a certain number of points through which the curve is drawn by hand, or by the use of "curved sets." The more numerous the lines, as *e f*, *b a*, *h g*, etc., the better, for a greater number of points will be obtained; and the more correctly will the curve of the spiral be obtained.

To describe the Spiral Scroll on a Handrail of a Staircase.

To describe the spiral "scroll" suitable for the termination of thehandrail of a staircase, as in fig. 45, draw the line *a b c*, and set off *a b*, the width of the rail, from *a* to *b* and *c*. Divide *a b* into four equal parts,

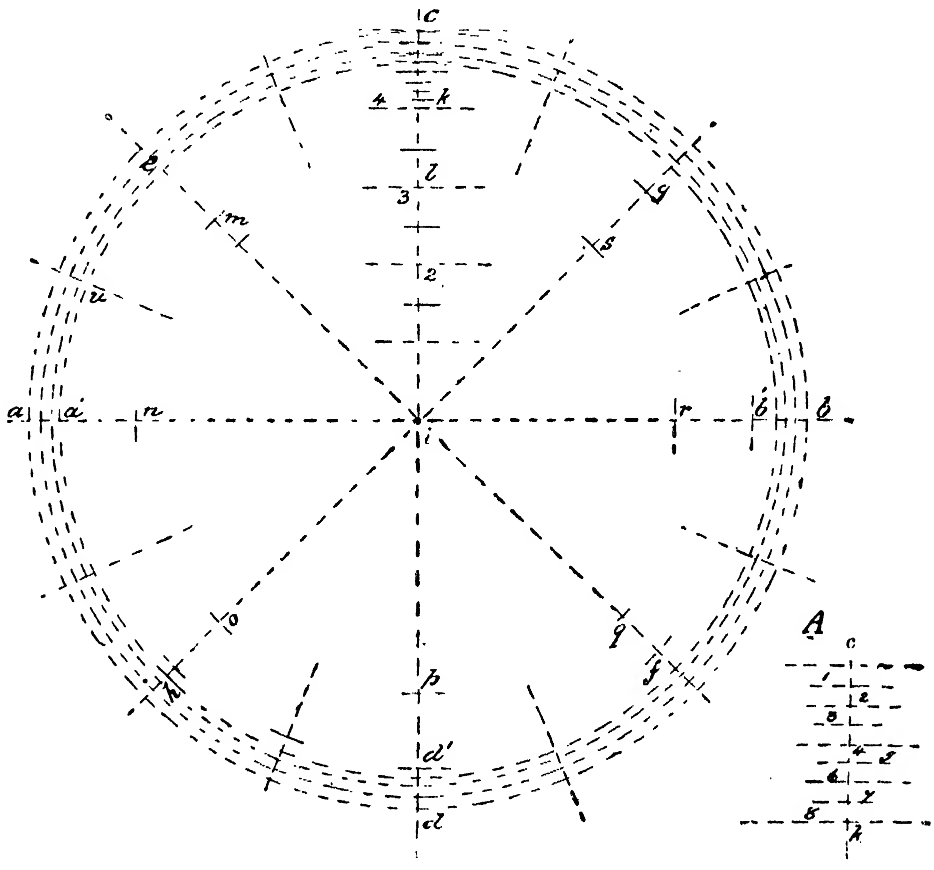


Fig. 44.

as there are equal angles formed by the lines *e f*, *a b*, *h g*, *d c*,—in the example eight. Then, from the point *i* as a centre, with radius *i* 1 (as the first part in *c k*, diagram A), set off the distance to the first line *e f*, cutting it in the point *e*. Next, from *i* with *i* 2 (second part in *c k*), set off the distance, cutting *a b* in *a'*. Next, from *i* 3, as before with *i* 3 (third part in *c k*), set off the distance, cutting the line *h g* in *h*. In like manner set off the distances *i* 4 (fourth part in *c k*), *i* 5, *i* 6, *i* 7, to the lines *i d* and *i c*, *i f*, *i b*, *i g*, cutting them in the points *d'*, *f*, *b'* and *g*. *k* is the next point in the spiral; the next division, *k l*, is then divided into eight equal parts, and from *i* as a centre, the first of these is set the same as the number of revolutions in the scroll. Take half of one of these parts, and set it off from the point *c* to points 1 and 4, and make 4 3 equal to 4 1; the points 1, 2, 3, and 4 are the centres of the quadrants. From point 1, with radius 1 *a*, cut a line *i d*, drawn at right angles to *a c* in the point *d*, by describing the arc *a d*. From point 2 draw parallel to *a c* a line 2 *e*; and from 2 as centre, with 2 *d* as radius, describe the arc *d e*, and so on. Scrolls may be drawn by dividing the proposed distance between each revolution into as many parts as there are revolutions in the scroll; and at the centre constructing a polygon with as many sides as there are divisions

or parts, each side being equal to one of the parts. Fig. 46 shows the enlarged centre of a scroll in which there are six curves shown with the curves described in fig. 47. The distance between two points —which give the width—as *a b* in fig. 47, being divided into six equal parts, *b* 1 being equal to *a b*, from 1 a hexagon is described, giving the points 1, 2, 3, 4, 5, and 6 as the centres of the arcs, the arcs being terminated at points on the lines found by producing the sides of the hexagon, as 1 6 to *i*, fig. 47, 2 3 to *d*, 4 3 to *f*, and 5 6 to *g*. "To describe the volute or spiral in fig. 48." Let *a b* be the breadth of rail. Set off this four times on the line *a e* to *c*. The point *d* will divide the distance between *a* and *c* into two equal parts. Divide *d a* or *d c* into equal parts, one more than the number of revolutions the scroll is designed to be; in the example this is three, so divide the eye in fig. 48 being too small to admit of the various numbers being given in the drawing). From the centre 1, fig. 48, draw a line 1 *f* at right angles to *a c*; and from 1 as a centre, with radius 1 *a*, describe the arc *a f*, cutting 1 *f*; from 2, parallel to *a c*, draw 2 *g*, and from the point 2 as centre, with distance 2 *f*, describe the arc *f g*, cutting 2 *g* in *g*. Parallel to 2 *f*, from the point 3, draw a line 3 *h*, and from 3 as centre, with radius 3 *g*, describe the arc *g h*. From the point 4 as centre, with radius 4 *h*, describe the arc *h d*. From 5 (see diagram A) draw a line parallel to 2 *f*; and from 5, with 5 *d* as radius, describe the arc *d u*. From 6, as centre, with 6 *u* as radius, describe the arc *u v*. From 7, with 7 *v*, describe the arc *v w*, and from 8, with 8 *w*, describe the arc *w m*. From 9 draw a line 9 *n*, parallel to 2 *f*, and from 9, with radius 9 *m*, describe the arc *m n*. From 10

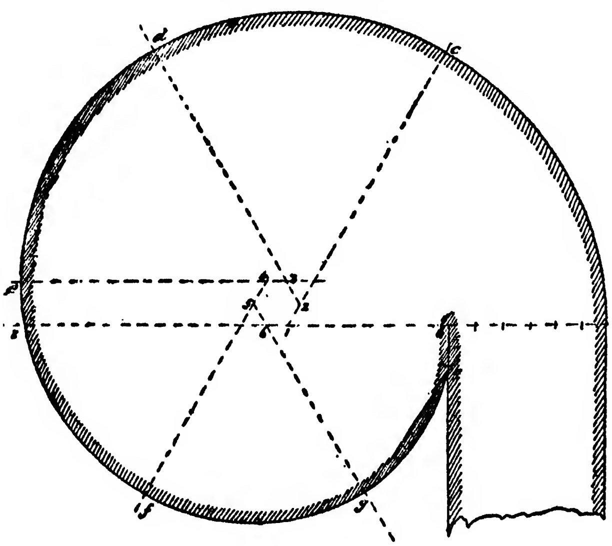


Fig. 45.

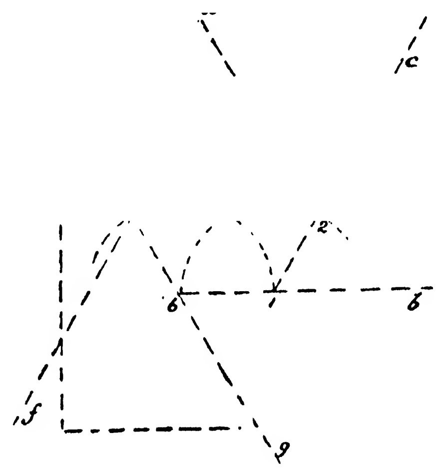


Fig. 46.

the parts *d c* into four equal parts; take half of one of these parts and set it off from the point *e* (see also diagram A, which is the eye of the scroll on a larger scale), on either side to the point 1 and 4; draw 1 2 and 4 3 parallel to each other, and extend them indefinitely. Make 1 2 equal to 1 4, and draw 2 3 parallel to 1 4, thus completing the square. Join *e* 2, *e* 3, and divide *e* 2 or *e* 3 into the same number of equal parts as there are to be revolutions in the scroll as three in the points 10, 6—11—7. Join 6, 7—10, 11, by lines parallel to 2 3, and 6, 5—7, 8—10, 9, and 11, 12, by lines parallel to 1 2, thus completing the internal squares. The corners of these taken and numbered in succession, commencing from the point 1, will be the centres from which the quadrants of circles forming the curve of the scroll in fig. 48 are described; the operations being as follows (the numbers of the centres being taken from diagram A, draw a line 10 *o*, and from 10 with 10 *n*, describe the curve *n o*. From 11 draw a line 11 *k*, parallel to 2 *f*, and from 11 with 11 *o*, describe the arc *o k*. From 12, with 12 *k*, describe *k l*. The arc *l q* is described from 9, the arc *q r* from point 10, the arc *r s* from point 11, and arc *s t* from 12. From centre 1, with 1 *b* as radius, describe the arc *b j*; from centre 2, with 2 *j*, the arc *j k*; from centre 3 the arc *k a'*, and from centre 4 the arc *b' c'*; from centre 5 the arc *c'* running into the arc at *o*.

Drawing or Describing of Helices and Screws.

Closely connected with the subject of spirals, of which we gave examples in the preceding chapter, is that of helices and screws.

We now direct the attention of the draughtsman to the delineation of the curves in winding or helical or screwed lines and surfaces. The curved line known as a helix, which is the base of all the forms we

describe as winding or twisted surfaces—such as screws, the propellers of steamships, and winding staircases—is that which is generated by the traverse of a point over and around a cylindrical surface. This surface may be that of a cylinder, as *a b c d*, fig. 1, Plate CLXXXII., with its sides parallel, or it may be that of a cone or the frustum of a cone, as *a b c d* in fig. 3, Plate CLXXXII. A fair idea of the nature of a helical or screw curve may be obtained by the following simple model diagram, as it may be called. Construct a triangle *a b c*, fig. 6, Plate CLXXXII., on a piece of thickish paper, of which the base *b c* is greater than the height or perpendicular *b a*, and mark the hypothenuse *a c* with a band in red or blue pencil. Cut this triangle out with sharp edges all round. and paper be turned round, still keeping them tightly in contact, till the exactly opposite side be looked at, the appearance presented will be as at *m n o*. The draughtsman will thus perceive that of this winding line only one-half of the bands or complete convolutions are seen on one side, the other half being on the other side of the pencil or cylinder, and that they must occupy the spaces between the bands on the first-seen side. This is shown by the view *m n o* of the side opposite to that at *f g h i*, in the relative position of the lines *m n o* to the lines *j k l*, indicated by the dotted band *p*. But this band would not be as in the direction at *p* corresponding to *m*, but would incline in the opposite direction, as at line *q r*. If, therefore, the model was to be delineated so as to show the band

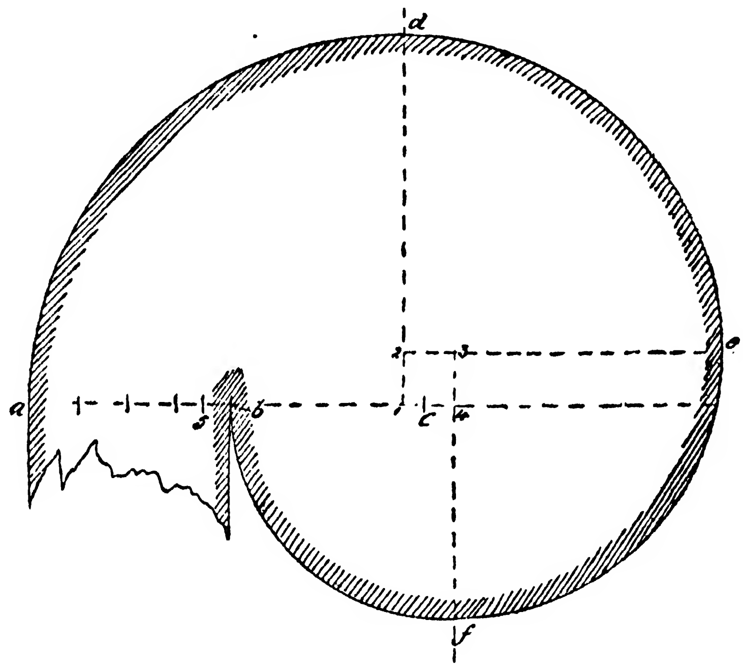


Fig. 47.

Take a pencil or cylinder of small diameter, and place the paper triangle in relation to it as shown at *d e* (fig. 6); then wrap the paper steadily and tightly round the pencil, and continue wrapping it round till the point *c* is reached. If the young draughtsman will closely watch the coloured edge *a c* as it shortens by being wrapped round the pencil, he will perceive that it forms a winding line gradually "coming down"—to use a familiar phrase—the pencil as the wrapping proceeds. When this is completed, and the point *c* reached at the foot *d* of the pencil, and the whole is held tightly, to prevent the paper triangle from unwinding, and it is held up straight before the eye so as to get what is called a front elevation of it, the appearance it will present will be as at *f g h i*, with the coloured bands as at *j*, *k* and *l*. If the pencil in its complete winding, one-half would be in full line, as at *j k l*, the other half in dotted line, as at *q r*. This is shown in the diagrams in fig. 4, Plate CLXXXV., and fig. 3, Plate CLXXXII., the helical line in front being in full line and hatched or cross-lined, the helical lines at the back, or those not seen in the front view, being dotted.

A helical line may be cylindrical—that is, when looked down upon in plan would show as a circle, the diameter at any one point of its horizontal section being the same, and this in consequence of the cylinder being parallel sided or of equal diameter throughout. Or the helical line may be conical, still circular in plan when looked down upon, but the diameter being less at the upper point than at the base, and this in proportion as the diameter of the cone or the frustum of

DEVELOPMENT OF SURFACES.

INTERSECTIONS OF SOLIDS.

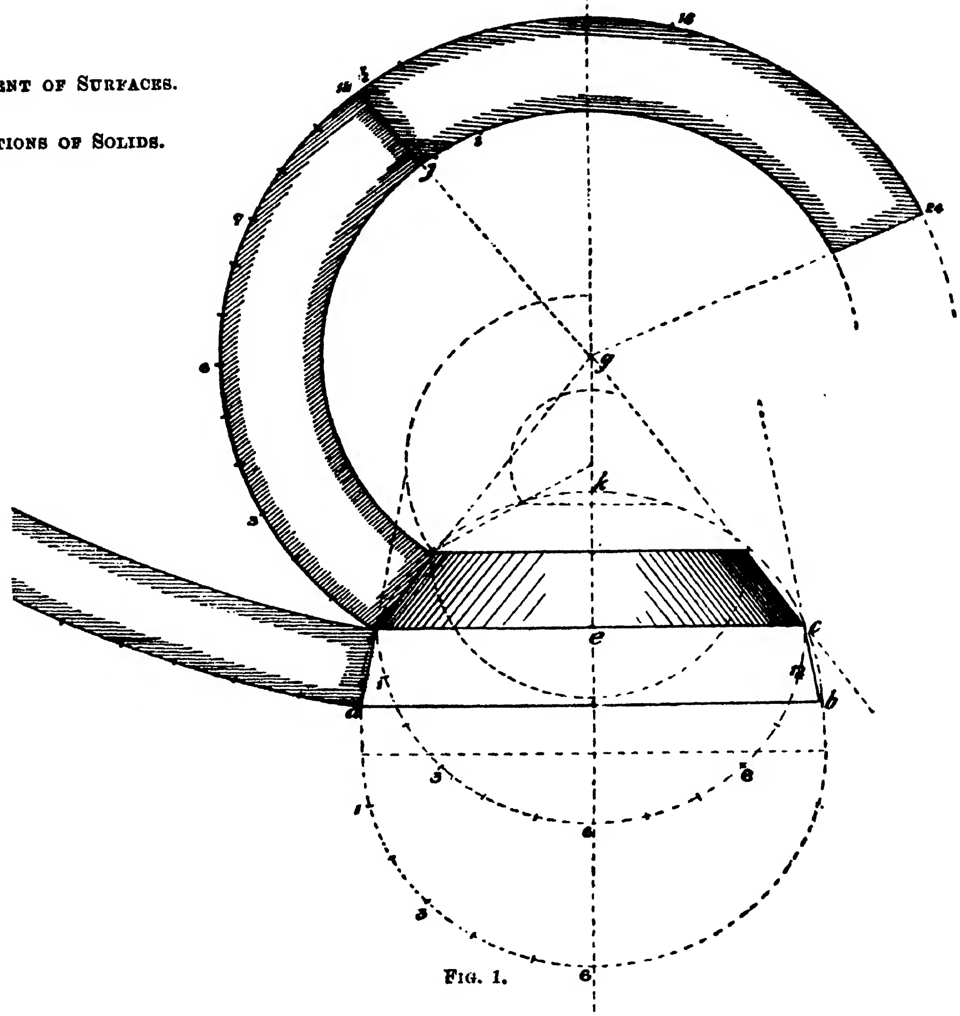


FIG. 1.

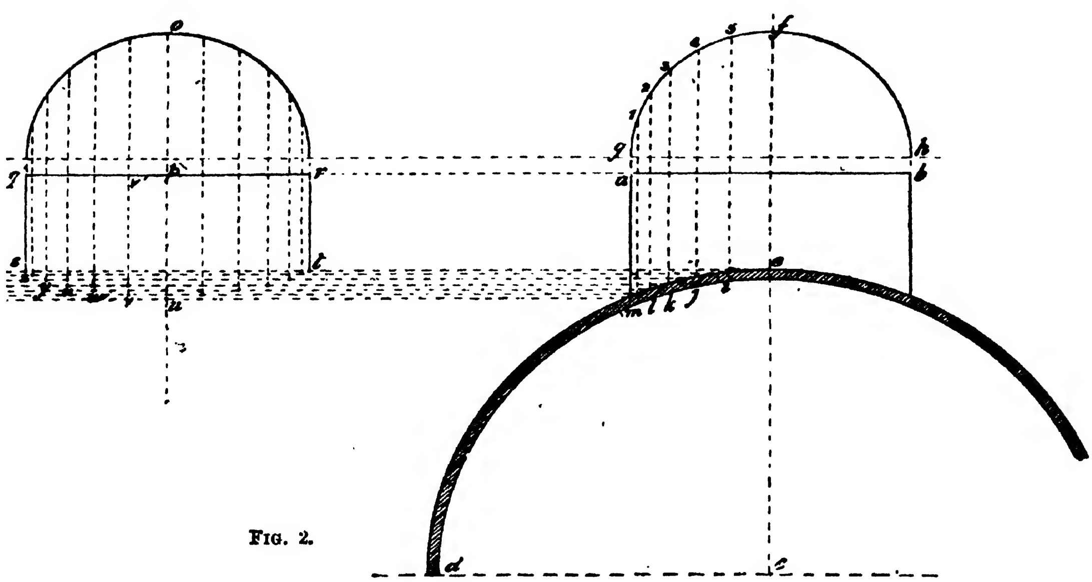


FIG. 2.

INTERSECTIONS AND INTERPENETRATIONS OF SOLIDS.

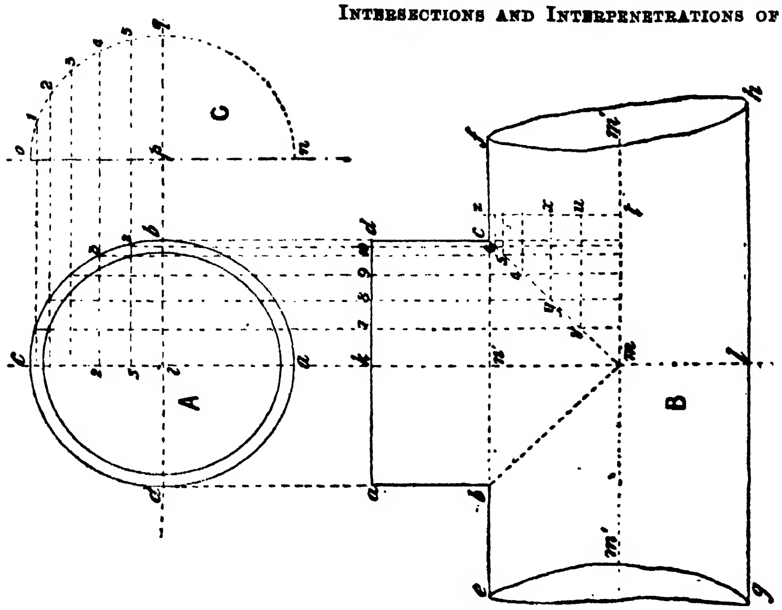
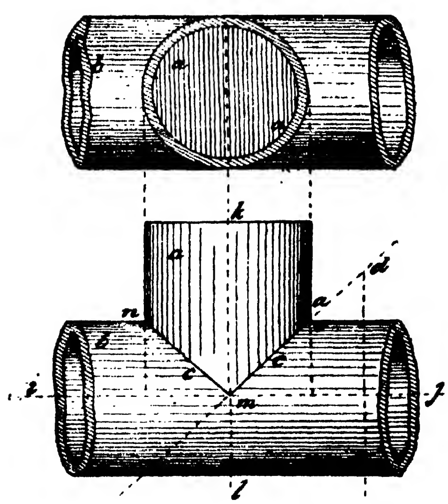


FIG. 2.



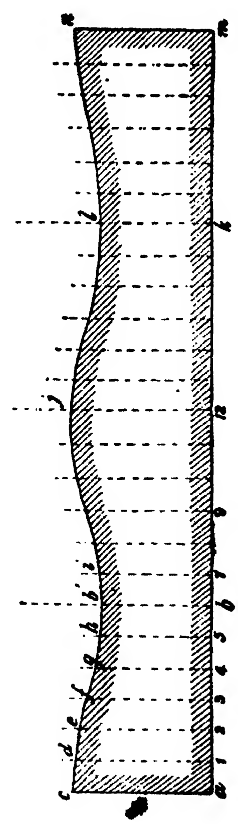


FIG. 4

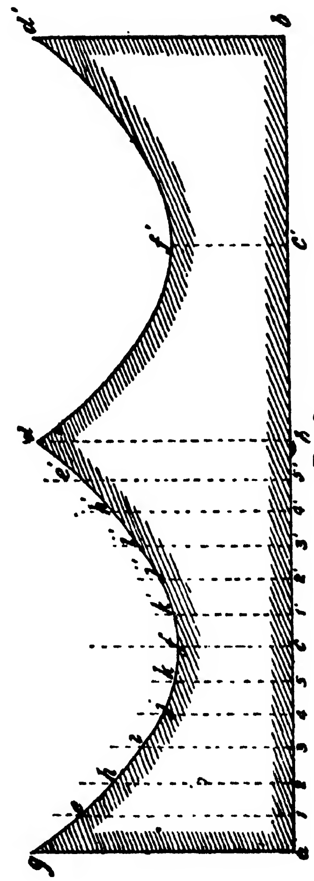


FIG. 3

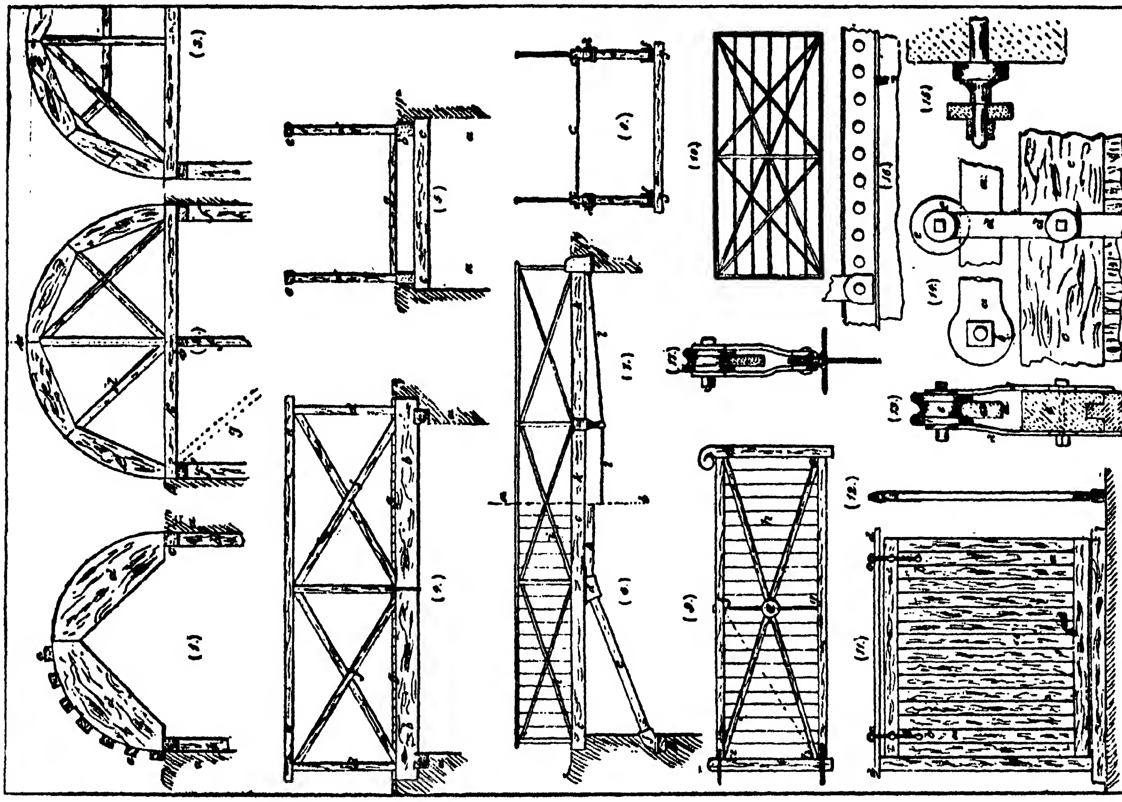


Fig. 2.

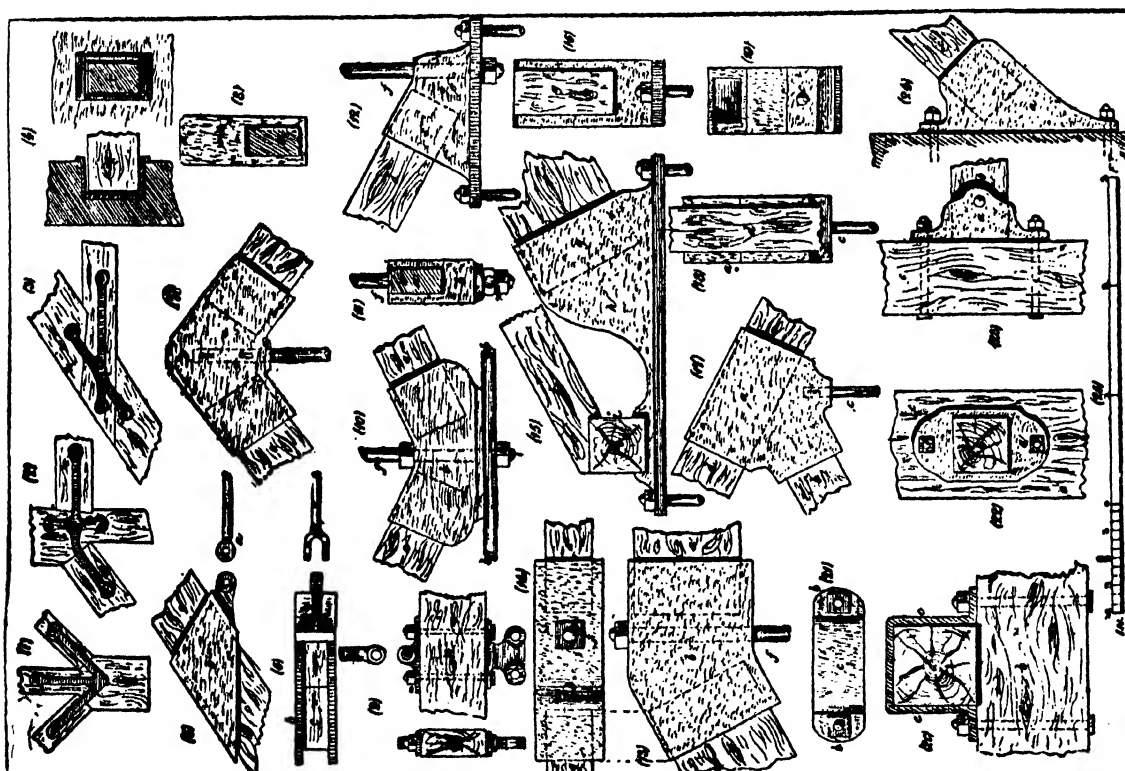


Fig. 1.

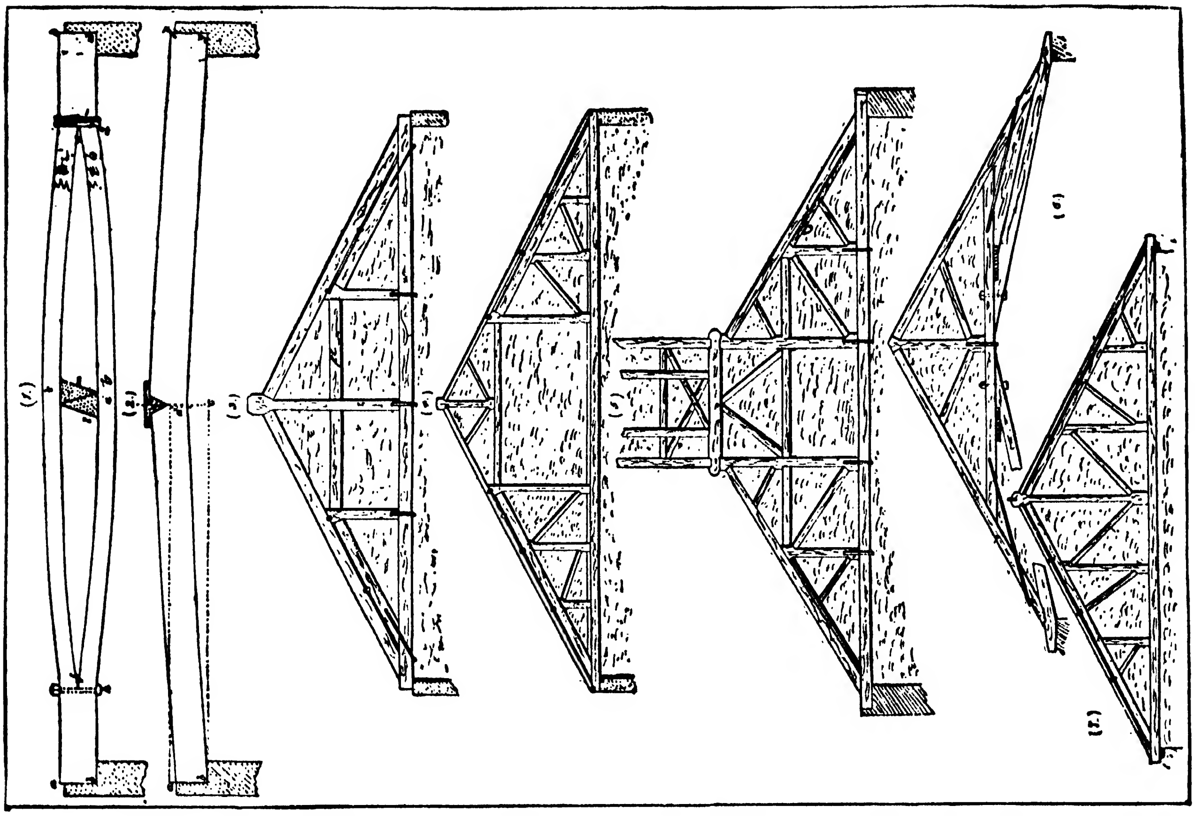


FIG. 2.

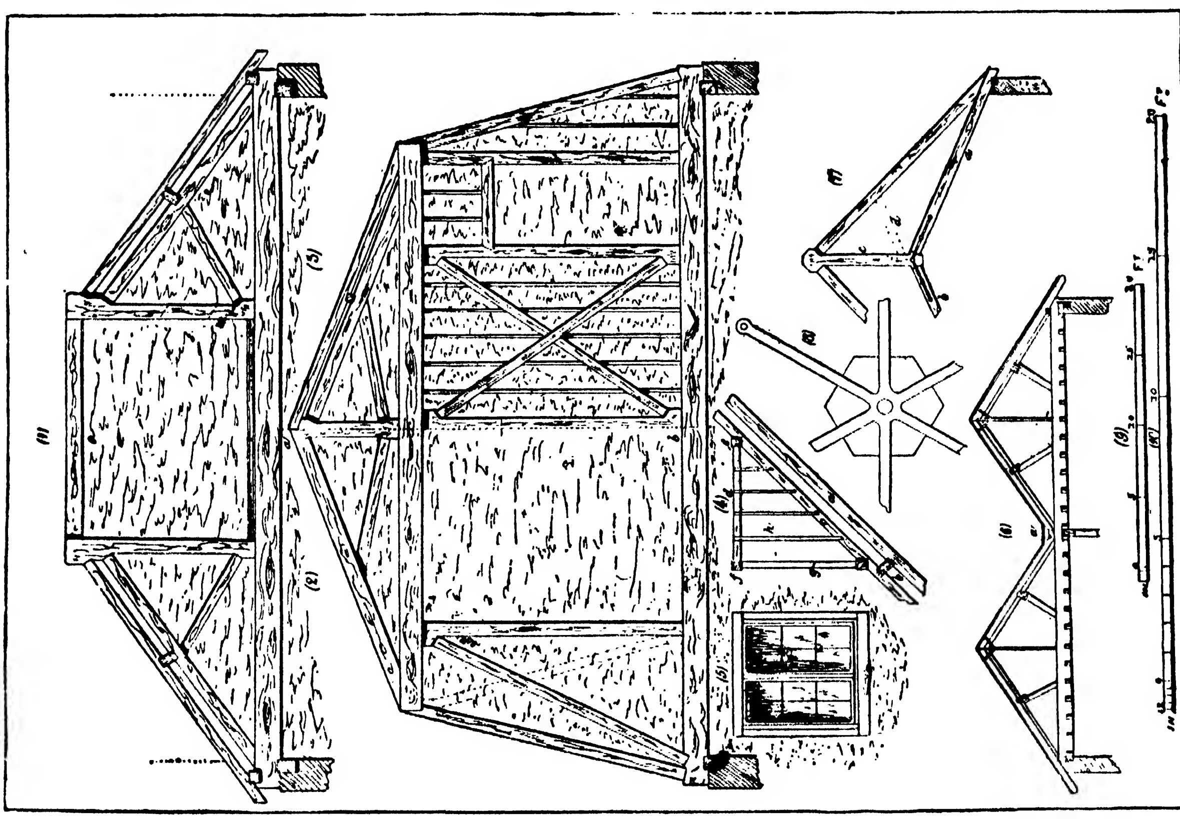


FIG. 1.

THE TECHNICAL STUDENT'S INTRODUCTION TO THE GENERAL PRINCIPLES OF MECHANICS.

LAWS AFFECTING NATURAL PHENOMENA—MATTER AND MOTION.

CHAPTER XXXII.

In continuance of the subject of the action of the windmill, begun in last chapter, we have to notice, in regulating the speed of the arms by the adjustment of the sails, they are covered or partially covered with, that if the wind be too strong, it is obviously necessary to do as the sailor does in like circumstances —that is, "take in sail," and in some instances, as may be seen in windmill working, "furl" one or two sails completely, so that one of the arms, if not two, are allowed to revolve with little or no sail-covering extended. In old mills the canvas covering was wound upon a roller extending along the whole length of the arm, and by turning this the sail was spread more or less over the surface, as desired. This was a tedious process, and involved the stopping of the mill and the careful attention of the miller, to watch and provide for the varying force of the wind. In improved mills the sails were divided into sections, each section or width being mounted on a separate roller, and the whole were under the control of a system of rods and levers actuated by or under the influence of a governor, of the type used in the steam engine, so that as the velocity of the arm increased beyond a certain point the rollers were wound up, and the surface being lessened the velocity was decreased. When the speed became too slow the governor fell, and unwinding the rollers, spread more canvas over the framing, and the velocity was increased. Notwithstanding the widespread employment of steam as a motive power, the use of windmills is by no means done away with. Great numbers are still employed in certain localities, and, so far as present circumstances seem to indicate, will be employed for a long time yet. Indeed, for some departments of work windmill power is on the increase, and in many colonial districts it cannot well be dispensed with. The various problems connected with the work are interesting, and the working details are fine exemplifications of natural laws or principles.

The Action of Fluids on Oblique Surfaces.—Mechanical Exemplifications.

The action of fluids on oblique surfaces in producing and in regulating motion is exemplified in many other departments of mechanical work, in addition to those already noticed. Supposing that in a dead calm, with the air quiescent, we applied such force to the shaft, *d*, of the windmill in diagram fig. 48 *ante*, as to make the arms, *b*, *c*, with their sails set, revolve, we should cause the sails to act upon the quiescent air, so that the pressure created on their oblique faces would cause the air to flow back, as it were, from the faces, as in the direction *l*; but the flow being resisted by the body of air behind, the reaction causes the sails to be in reality forced back in the direction of the arrow at *n*; so that the shaft *d* is forced end-on inwards towards its bearing or top. This action probably gave rise to the invention of the propelling screw. A screw proper is simply an inclined plane rolled round a cylinder, the diameter of the boss or cylinder and the obliquity or angle of the inclined plane regulating the character of the turn of the plane round the cylinder, and the distance between its

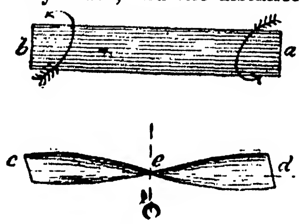


Fig. 52.

edges as they are successively carried round the boss —in other words, giving the pitch or twist of the screw. If we take a piece of flat, flexible material, as *a b*, fig. 52, and holding it fast between the thumb and forefinger of one hand at *a*, and by the other at *b*, giving the wrists a turn in opposite directions, as shown by the arrows, we obtain a twisted surface, as at *c d*; and if the twist or turn has been equal in force at the ends *a* and *b*, the twist will be equal, though in opposite directions, on each side of the

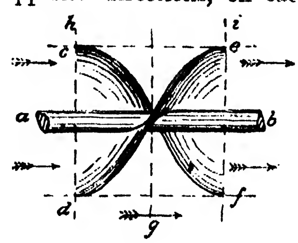


Fig. 53.

central point *e*. The twisted surface here obtained is part of a *helix*, or screw; and if we suppose that the twist be completed so that the ends form a circle round the axis or centre line—shown dotted—at *c a d*, we have a screw, as in fig. 53, which is virtually a flat surface twisted regularly round—that is, the twisting force in one direction being equal to the twisting force in the opposite direction—a central shaft or axis, as *a b*. If we suppose this screw to be placed in water flowing at a certain velocity in the direction, say of the arrow *g*, this striking the oblique surfaces, as at *d* and *e*, perpendicularly, the result is a force tending to push, so to say, the points *e* and *f* outwards; but as these are rigidly connected with the shaft *a b*,

the lateral motion is converted into the circular one of the points *e* and *f*, as in the direction of the arrows in opposite directions, and the consequent circular motion of revolution of the shaft *a b*. We can thus convert the rectilineal flow or force of the water in the direction of arrow *c* into a turning force of the shaft *a b*, which may be led off to any point desired by appropriate mechanical arrangements. Conversely, in place of

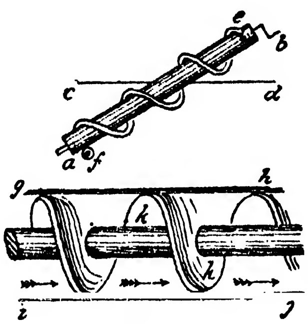


Fig. 54.

having the water flowing onwards, we have it still or in a state of quiescence; and if we then give by some means or another a motion of revolution to the shaft *a b*, the screw blade striking the water at different angles of obliquity, we have precisely the converse or opposite result to that of the arrangement above named, and we thus cause the water to be moved along in the direction of the arrow *g*. If we place the screw shaft at an angle *a b*, oblique to the surface of the water *c d* in fig. 54, and twist a pipe helically or screw fashion round the shaft, we get an inclosed and inclined screw; and if the lower orifice, as at *f*, be immersed in the water, we can by causing the shaft and its screw pipe to revolve, lift a portion of the water from a low level, as *f*, to a high one, as *e*. This contrivance, sometimes used in hydraulic mechanism, is known as the Archimedian hydraulic screw, its invention being attributed to the celebrated ancient philosopher Archimedes, and hence its name. This contrivance is adapted in many ways to the mechanism of industrial work. As a carrier or mover of granular substances from one point to another in level or nearly level directions, and also in raising those substances from a low to a higher level, the Archimedean screw proved itself of great utility. A well-known adaptation of it is the "malt carrier" in breweries and the "flour carrier" in flour mills. The malt or flour is conveyed in an open semicircular trough, or in a closed tube, as *g h i j*, the radius of which is a little in excess of the radius of the screws *k*, *k*, in fig. 54, so as to admit of a little "clearance" between its periphery and the surface of the trough. The flour or malt is supplied at one end of the trough, and is conveyed or carried along to the other, where it is delivered by the continued revolution of the screw—the shaft of which is set and kept in motion by appropriate gearing connected with the "line" or "lying" shaft, receiving its motion from the prime mover. The blade of the screw as it revolves comes round in contact with the flour or malt, and entering amongst the particles and descending through them in a direction oblique to the line of direction of the trough, shoves it, so to say, forward, between one face, the inner, of the screw, and the other face, the outer, as between the points *h* and *i*, fig. 53; and the supply of material to the trough being continuous, this shoving or propelling motion is also continuous, so that the portion passing along between the two first convolutions or blades of the screw is passed on to the next two, and so on to the last, or point of delivery. There is no stirring or lifting up of the material as the blades revolve: they seem, in fact, looking at the apparatus in work, as if they merely kept revolving in the midst of it without giving any progressive motion to it. The young mechanical student will derive some lessons useful in his practice if he watches closely the work done by a screw carrier when he has the opportunity to see it in operation.

Further Mechanical Exemplifications of the Action of Fluids on Oblique Surfaces.

If an Archimedian screw, in place of revolving in still water in a fixed position, be placed in a vessel floating in and capable of moving along the water, as the screw *a*, fig. 55, at the stern of a boat *b c*, the water, as the screw is made to revolve, is passed along its blades in the direction of the arrow *d*; and as one blade at a certain angle creates a motion in the direction of the arrow *e*, another blade at another

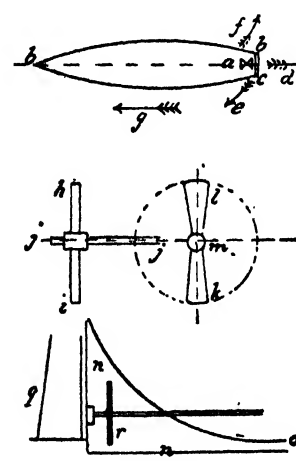


Fig. 55.

angle gives a motion in the direction of the arrow *f*, but as the blades are of equal obliquity and opposite, the motions on each side, *e* and *f*, are also equal and opposite, and the resultant of the two is a motion forward of the vessel in the direction of arrow *g*, just as if the vessel were pushed forward by a pole pressing

in the direction of the arrow *d* on some solid and fixed body placed at its point. Such is the principle of the "screw," used almost to the complete exclusion of the "paddle-wheel" propeller for steam vessels. It was first applied, many years ago, to the propulsion of canal boats, for which it was peculiarly well adapted, as there was neither breadth of surface nor depth of water at the sides to admit of the use of side paddle-wheels—which, moreover, caused much damage to the banks by the tidal waves they created. But from lack of a due consideration of the conditions under which the old contrivance of the Archimedian screw was adapted to this work, the inventor failed in making his application a success. It was not till a mechanician of the name of Smith, some half a century ago, adapted the screw to sea-going vessels, that its value began to be recognised; and by the efforts of a host of succeeding inventors it was made so thoroughly efficient that screw-propelled steamships, both for coasting and deep-sea voyages, are the rule, paddle-wheel steamers being altogether the exception. In the Navy screw steamers are alone used, the only exception being in "despatch boats," which are employed for special purposes where speed is required; for the screw can never—has at all events as yet not been able to—compete with the paddle as a means of giving speed to the vessel in which it is employed. But the other advantages possessed by the screw, —and none of which can be obtained from the use of the paddle-wheel—such as the small bulk and weight of the screw, its being placed in a situation beyond the ordinary range of shot, and so that it does not interfere with the sailing qualities of the vessel, thus enabling the steam-worked screw to be an auxiliary power to that of the sails, etc., etc., are so great that it is in practice considered better to submit to the sacrifice of a certain percentage of speed by its use, than obtain the higher speed by the use of paddle-wheels with all their disadvantages. Nevertheless, by the improvements effected in screw-propelled vessels, all are now regularly worked, giving for the longest voyages a marvellous rate of continued speed.

The Screw Propeller.

In the modern screw propeller the screw is much modified from its original, or what may be called its normal form, as in diagram fig. 53 *ante*. In this, the usual form, the blades, *e*, *f*, are continually applied round the central shaft *a b*; so that the helical surface is uninterrupted from one end of the screw to the other; and the twist, or what is technically called the "pitch," is such that the complete arms of the blade are pretty frequent or close together in a given length of the shaft or central boss. In place of a continuous, an interrupted blade is used in the screw propeller; in general practice this is carried to such an extent that a part only of the helix is used; and the screw as seen in plan and elevation has two blades, as *h i*, *n k l*, fig. 55, projecting from opposite sides of the central boss of the shaft, *j j m*, by which motion is given to the screw. The position of the screw in relation to the vessel is that part known technically as the "dead wood," as *n n*, which is in line with the keel *o* of the vessel, and runs up to join the lines of the stern *p*. This dead wood is placed before—reckoning from the bow or forward part of the ship—the rudder *q*, which must of course be the last or extreme outer part of the vessel. An open framework, *r*, is placed in the dead wood in which the screw works, as shown in the position at *h i*, and the screw shaft *j* passes through a water-tight stuffing box at *s*; the outer end of the shaft working in and bearing up against a step, fixed to the framing in the dead wood *n*.

The forms of screw blades and their pitch introduced from time to time into practice have been very numerous; and those proposed, but which have for

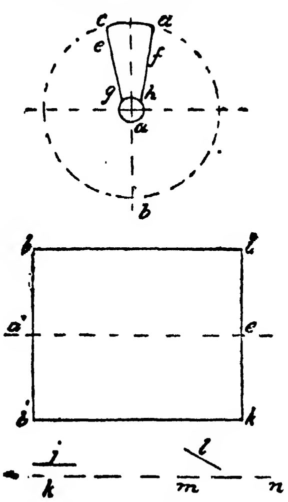


Fig. 56.

one reason or another met with but little, in some cases no success in practical working, are more numerous still. A record, indeed, of all that has been done and proposed in connection with screw propellers would take up the space of a very large volume. A few notes, however, in connection with it will be useful here, as explaining further the point we have at present under consideration—namely, the action of fluids upon oblique surfaces; or the converse of this, the action of those surfaces upon fluids, acccording as the one or the other is in motion in relation to the other which is at rest. If we complete the circle of which the ends of the blades *k*, *l*, diagram fig. 55, form the screw, this circle might be looked upon as a flat disc, the surface or any one of its diameters, as *a b*, *a' b'* in diagram fig. 56, would be at right angles to the shaft or line *a' e* passing through the centre. The blades, as *a*, *d*, *e*, diagram fig. 54, are not parallel, as at *j*, to the supposed disc

k (a' b' b), but are placed oblique to it, as at l. This angle or degree of obliquity is not, however, continued the same throughout the whole length of blade from the tip or outer edge, d c, to the centre where it joins the boss or shaft a, but it varies, being greatest near the boss a and least at the ends d, e, where it nearly approaches the parallel position at j, as forming a very small angle with the face of assumed disc k. The reason for the obliquity increasing as the blade approaches the boss a, and as the width of the blade decreases, will be obvious on considering that the speed or velocity of the water passing over the surface of the blade is a uniform or unvarying quality, while the angular or circumferential velocity of the blade at various points of its section is a varying velocity. Thus, it is evident that the space through which the part of the blade taken on the sectional line h i passes in a given time is greater than the space passed through in the same time of the part of the blade between points f and g; the speed of the tips, as d, c, is therefore much greater than the part nearer the central boss a. The water passing over or past the whole surface of the blade at the same or a uniform velocity, and as the surface on which the water acts is much less at the narrow parts of the blade, as f g, than at the broad parts h i, by giving the greatest obliquity to the narrow parts a greater grip, so to say, of the water is obtained; the proportion is thus equalised over the whole surface of the blade.

Mechanical Terms connected with Screws.

If the blade, in place of filling up but two spaces or divisions of the circle, as in the ordinary form of screw propellers, as at l k in diagram fig. 55, filled up the whole space, and was continued round the shaft till the general curve due to the screw as a a whole was wrapped, so to say, round the shaft, it would assume the completed form as in diagram fig 51 *ante*, its length being comprised within the space bounded by the dotted lines h, i. This distance g h is called the pitch of screw. And by the term pitch, as applied to a two-bladed propeller screw, is meant the distance between the two points or lines b' a' b' and k l in fig. 56, being those where a line drawn parallel to the axis of the screw a' e would cut the edges of the blade if it were continued round the shaft till the screw was completed as at i h in fig. 53 *ante*. The length of the line as b' l in fig. 56, gives, therefore, the pitch of a propeller screw, and is generally taken or expressed in feet. At first sight the student would suppose that the propelling power of the screw would be that due to the oblique action of the screw of a determinate pitch, and that every complete revolution of the screw would pass any body or point of the water along the blade of the screw from the point, as b, where the revolution began, to the point l, where it terminated. But the power due to the theoretical conditions of the screw and the water in which it turns is greatly modified and lessened by the practical conditions in which the screw works in relation to the water and the ship which it has to move or propel along. Considering the water as a solid yet mobile body, the screw in revolving and at the same time progressing or moving forward in it,—for the two are coincident, or in action at the same time,—insinuates itself, so to say, into the body of the water; but what may be called the "grip," due to the obliquity of the blades, on the water is not continuous, but at times loses its hold or slips from the water, so to say. By the existence of this loss, technically called the "slip" of the screw, the difference between the theoretical and the actual speed of the vessel propelled by the screw is considerable, varying from one-fourth to one-third.

Further Exemplifications of the Action of Fluids on Oblique Surfaces,—Projectiles.

The action of fluids on oblique surfaces is very finely illustrated in that important department of

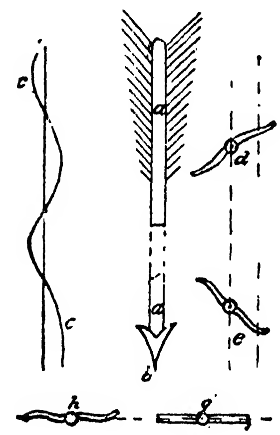


Fig. 57.

the mechanic's art—projectiles, to which of late years a variety of circumstances have given remarkable prominence; and which has given rise to an exceedingly wide range of inventions and of mechanical work, designed to give greater power and precision to ordnance, and conversely greater strength to surfaces such as the sides of vessels or the walls of forts, in order to resist this power. The action of fluids on the oblique surfaces of a body which is projected or shot through the air by some force is well exemplified in the case of the common arrow. This, as well known, is a long straight rod, a a, fig. 57, tipped or shod with a metallic barb or dart, pointed as at b to penetrate the object aimed at. Thus furnished, however effective it might be in penetrating any body which it might strike end-on, there would be no security that the object aimed at would itself be struck.

THE GRAZIER AND CATTLE BREEDER AND FEEDER.

THE TECHNICAL POINTS CONNECTED WITH THE VARIETIES OR BREEDS OF CATTLE—THEIR BREEDING, REARING, FEEDING, AND GENERAL MANAGEMENT FOR THE PRODUCTION OF BUTCHERS' MEAT AND OF DAIRY PRODUCE.

CHAPTER XXV.

In using the cultivator or grubber alluded to at end of last chapter for the getting rid of weeds, it is to be noted that while this implement tears up many of the weeds by the roots, others, such as the thistle or dock —if the latter has been allowed to go to seed—it simply breaks off. The weeds thus left loose should not be allowed, as some farmers allow them, to lie on the surface, in the hope that they will decay, and in so far act as manure. They may do this, and in a limited sense will; but the benefit derived in this way will be far outbalanced by the evil done; many of them again taking root, and growing up as future pests. The true method is to collect them with the harrow or cultivator, and carry them off to the compost heap; to which they will make the best addition if they first be dried and then burnt to fine ashes.

Where this radical method of treating the surface of weed-infected grass land is not adopted, or considered unnecessary, a close and a constant warfare should be maintained against the weeds. This, in the case of the broad-leaved plants, is best done by keeping mowing them down. They will ultimately give way to this treatment, which, however much it may be looked upon as troublesome, is at all events effective. In the case of the thistles, and indeed in that of the docks, which are long taprooted plants, the best way is to pull them out by the roots, either by hand—when the soil is soft by long continued rain—or by the hand tool known as the dock spade, or spud. We have known a field badly infested with docks effectually cleared by the use of an artificial manure of salt, soot, and nitrate of soda, this last ingredient being the bulk of the manure. One word as to "weeds." Anything in a pasture field not a grass is held to be a weed, and therefore, if possible, to be got rid of. Some of our readers may be surprised to learn that beyond any doubt some of the so-called weeds of pasture lands play as useful and as important a part as the grasses. They are, in brief, what sauces, salt, pepper, and the like, are to the food of man—the condiments of cattle. That our farm animals are specially fond of certain plants is well known; but it is not so well known that they are favourites to all the animals alike. On the contrary, each animal has got its own peculiar favourite plant or weed. But such plants are not merely to be considered as condimental or flavouring substances; some are also medicinal in quality. We do not go quite so far as a well-known agricultural authority, who maintains that as yet we know nothing compared to what we should and might know of our grasses and their accompanying weeds so called, and of their remarkable and indeed common or general properties as substances useful for feeding and also for health purposes; but we

our pasture lands and our meadows, and what is grown upon them.

Diversities in Grass Lands for Diversities of Feeding Stock.

We have in a preceding paragraph pointed out the fallacy held by many, and which may be expressed in the saying, "grass land is grass land, and there is no more to be said about it," and the corollary or deduction drawn from this, that all are alike valuable. We have shown how erroneous this is, and how numerous are the points which really influence the value of pasture lands. We have here to allude to another fallacy,—which is, that as all our farm animals, the cow, the fatting ox, the horse, and the sheep, are fond of and can live upon grass, if we have grass land at command it will be equally valuable, whatever its characteristics, for all those or any one of those animals. On which it is only necessary to remark that every sound practical grazier knows that, so far is this from being true, the exact converse is the case, and that therefore we have our "cattle" or "bullock grazing lands," and our "sheep grazing lands." That is, this distinction is a practical one where grazing is scientifically and systematically carried out, with a view to get the highest economical results. And, as we have thus two great divisions, we have also subdivisions, so that we find that grazing which will give good results for one breed of bullocks will give very indifferent results for another breed. Thus, where the massive shorthorn—and in some respects the remark holds equally true of its great rival the Hereford—bullock would find such insufficient pasturage that it would not thrive, another breed would find a sufficient supply of food to make it in good condition. But there is yet another fallacy but too prevalent amongst farmers and graziers of a certain class—namely, that "if you have your grass lands, and those of good quality, that is all that is needed." A great deal more, however, is required than this merely having a good supply of food for your grazing stock. For the man may have his larder or provision storeroom filled to the full with the best of everything, and yet get but little ultimate good out of it all; while another will do a great deal more with a less supply of substances. In the one case there is a wasteful or thoughtless, in the other a careful use, and we all know what the results of those antagonistic methods of dealing with substances of any kind are. And just so with grazing

lands: there is a way of so feeding them off with the stock that the very best results are obtained; another way which gives only indifferent, sometimes positively bad results. How and in what way this is brought about we shall see as we proceed, where we take up the subject of the management of grazing stock.

Necessity of a Knowledge of Grasses on the part of the Grazier.

We have said that a knowledge of our nutritious grasses is necessary on the part of the grazier aiming at carrying on his business in a scientific and systematic way. To become a thorough master of the subject would require close and systematic study not only of its scientific details, but a close observation of the peculiarities and habits of growth of the different varieties. In its extended and comprehensive practice it indeed forms a speciality, which to be thoroughly successful in may be said to require a lifetime of study and practical work. And it is a speciality which abounds in a vast variety of most interesting details. It is but few who have made it thus a speciality, and have given to the world the results of their devoted labours. We have thus comparatively few published works of authority on the subject. The oldest, if not chief of these systematic works, is Sinclair's well known work on grasses, which may be said to be the great authority. Parnell on Grasses is another authoritative work. Several of our leading farming authorities and of our agricultural seedsmen have of late years paid special attention to those departments of the naturally wide subject which have a more direct and special bearing upon the practical cultivation of those grasses fitted for permanent pastures, grazing, meadows, for haymaking, and for alternate husbandry, or artificial grasses for cutting and soiling, so that the published results of their experience in field trials and experimenting places at the disposal of the young grazier a large store of highly useful information. The close study of the subject to which we have alluded cannot be expected to be given by the grazier, who has all the labour of his daily work and the cares of his business as a buyer and seller to engross his attention and take up his time; but nevertheless, if he has the ambition to occupy a high position in his calling, and to be of practical service to his fellows as an authority, he ought at the least to have a thorough practical knowledge of the special grasses which are the most valuable for the purposes of his trade. Those—fortunately or unfortunately, just as the subject is viewed—are so comparatively few in number that it will not take much time to become well acquainted with their external peculiarities and with their habits of growth. We should, in the case of the young practician—if not in that of him who is more advanced in years and possessed of a wider experience in practical details of grazing—strongly recommend him to set aside a small extent of land, carefully prepare its soil, and set out its surface in compartments or squares, separated by as wide alleys or walks as the ground space will admit of, so as to keep the squares as distinctly separated from each other as possible. One of these squares should be devoted to the sowing and ultimate cultivated growth of one variety or kind of grass. It will be all the better if two or even three squares or plots are given to *one* variety, taking care that those squares are in different parts of the general plot. A rough paper plan of the whole of the plots or squares should be made, and the names of the varieties and their dates of sowing should be recorded on each square of the plan, corresponding to the position of the square in the general plot of land. This written plan of squares should be so large as to admit of notes being inserted, such as respects dates of coming into flower, and other points noticed. By some such arrangement as this, more or less modified, the young grazier would find that he had the means of becoming practically acquainted with the most valuable grasses for permanent pastures and meadow lands, their peculiarities, habits of growth, etc , etc. The growing experiments however, should not be confined to those departments, but should embrace the artificial grasses, as Italian rye grass, the clovers and other forage plants, such as Lucerne, useful for cutting and soiling purposes, and for the new method—or rather the recent introduction of an old system—of preserving forage known as "ensilage," hereafter described. We can promise the young grazier—for we have tried the system—not merely the acquisition of much useful information by the adoption of the plan here recommended of experimenting; but a vast deal of intellectual pleasure, which in more ways than one he will find very fascinating.

Judicious and Economical Feeding off of Pastures by Stock.

We have said that it is not enough that the grazier should be possessed of good lands, and those covered with nutritious grasses, and the whole kept in a condition of high cultivation: in order to make the most of his pasture fields it is further essential that he manages his "feeding them off" under certain rules or principles. We have shown the necessity which exists for attention to the points just now named; but, as we have already hinted, the grazier may possess "grazings," as they are technically called, or grass pastures of the best quality, and those well adapted in their variety for the class of live stock he is grazing, yet may fail to secure the best paying results, simply because he is not economical in his feeding off of the grasses at his command. So frequently is the practice followed that it may almost be said that it is the rule for graziers to overstock their land. They either put too many "beasts," as fattening and store cattle are

technically called, or too many sheep, on a certain extent of land; or if they put on fewer they keep on feeding for a longer time. In both cases the result is that the grasses are "cropped off" too short, or "eaten down" too close. And the result is a certain loss of productiveness in the fields, and also a loss in the retarded fattening or feeding of the animals themselves. The system of overstocking of grazings incurs therefore a double loss. The last-named source of loss the inexperienced reader will more readily understand than the first, for if too many animals are "put up" on a certain extent of grazing it is obvious that they must have less food than they require. But the reader may not see so readily how this system of overstocking has a bad influence on the productiveness of the pastures themselves. The point involved is one of great practical importance, and may be stated thus. The grass plants have a natural tendency to keep up a continuous growth; this of course varies in different seasons and under different circumstances of soil and climatic influences: when eaten down by stock this tendency to grow or to recover their original or normal state of growth is in proportion to the extent to which the eating down has been carried. If too much eaten down, so that a certain point is reached, the recuperative power of the grasses, or their tendency to grow again, is very much lower in proportion than if the eating down process had been stopped before this low point had been reached. We may illustrate the point arithmetically thus. Suppose the normal extent of growth of the grass to be two inches high or deep, we put in stock to eat it down to a height of one inch; we then take the stock off the grazing, or "lay" or "ley," and we find that a fortnight's rest suffices to bring the grass up to its normal or two-inch height. This may be called the measure of the recuperative or recovering power of the grass. But suppose we eat the grass down to a height not of one inch, but of half an inch, we do not find now the same proportion to exist as regards its recuperative powers. If it did it would take three weeks' rest to get up to the normal height of two inches, but as it does not, it actually takes four to five weeks. And the further we go on the descending scale, that is, the more closely we eat down the grass, the more do we lessen its recuperative power. And the ratio in which this is decreased in proportion to the increase in the length of time during which the grass is being fed off increases very rapidly,—so much so that a point is soon reached at which it is very difficult indeed for the grasses to recover at all, permanent deterioration frequently resulting, and even when recovery takes place it is found that overstocked grazings rarely get up again to their original good condition. In giving this arithmetical illustration of a point which literally lies at the root of the economic administration of grazings, we do not of course give what are the actual proportions: all that is done is to show the relative results of relative conditions of different kinds.

Changing of the Stock from One Field to Another.

We have said that this over-eating-down of grazings may be done in two ways,—by keeping a comparatively small number of animals a longer time than a greater number on the land. The two results look, but are not in reality the same. The evil done to the pastures is greater with the greater number than with the less, for the poaching and cutting up of the surface of the field is more hurtful with the greater number. To avoid the two great evils of the system of overstocking or overfeeding off pastures, the deterioration of the grasses and the short feeding or part starvation of the animals, it is obviously necessary that the grazier should have the command of more fields than one; so that when the proper "bite" or amount of feed fails, or the point is reached at which the judicious grazier would take the animals off the grazing, he will have another field in good condition to take them to. And this "good condition" will in itself be also and best secured if the fields are so proportioned and arranged that each will have its due length of time to recover the growth of its grasses, and that each will never be eaten down below the proper point.

This changing of the stock from one field to another will, as in all other classes of work, be the more efficiently as it is the more systematically done. And the young grazier has the greater encouragement to this in the fact that the system carries with it other advantages than those we have named. Thus the change of fields is in effect a change of food, inasmuch as it very rarely happens—if indeed it ever in practice does so—that two fields, even contiguous or closely contiguous ones, have grasses or a "bite" of the same character. However closely the nature of the pastures in the two fields appear, there is always some difference,—some plants, for example, not strictly grasses, the weeds so called, which we have seen to be not altogether useless, being present in the one field which are not present in the other. And the advantages of a change of food physiologically we have in another part of this section fully shown. But although this change of "bite" or food is beneficial to all classes of stock, it varies in the proportions of its efficiency. Thus a wide range of bite, that is of different pastures, seems to suit young stock which are being pushed on better than more advanced animals. And if we consider the physiological circumstances of each class of animals, we can easily enough understand how this should be; for it is in the earlier stages of the animal growth or life that the "impressions" are received which, being retained, give

what is called the character of the matured animal, and these being received and this developed it is maintained with comparative ease. Less food, for example, is required to keep an animal *up to* or at the point of good condition than is necessary to bring it *from* a low up to this high condition.

This bringing of animals from a low condition to a high, the reader will perceive, constitutes in reality the whole work of the grazier; and the doing of it quickly and economically forms what may be called his "art." And it is in the closest connexion with this that lies the value of the system of changing the pastures, or of varying the "bite." We have said that this value depends greatly upon the systematic way in which it is carried out. The fields of a grazing farm are, as we have seen, of a varying character as regards the kinds and qualities of their grasses and plants. And this is in almost all cases so marked that the grazier has but little difficulty comparatively in marking off some as worse in quality than others, so that he has thus to hand, as it were, classes rising in value. The principle in using these is comparatively simple, and it lies in beginning the young stock and store cattle with the poorer pastures and gradually taking them up to the richest when they are ready, or nearly ready, for market. This practice is advantageous in another respect: the store, or those cattle which have been brought in for being fattened up for market, if not in good condition in the spring, if put at once in good or too rich pastures would receive harm. If a pasture not absolutely poor is not available for this purpose, the cattle may be put into a field which has had its richest part already eaten off by advanced stock.

The details of the system of change of pastures will necessarily vary on different farms and in different localities. It is impossible practically, therefore, to lay down a rule applicable to all circumstances; the grazier being determined in his plan by his circumstances, both as regards the number and the extent of the fields he has for pasturing. As regards the extent, it will upon the whole be better to have a greater number of small fields than a few of large acreage. He will thus be able to carry out a more perfect system of classification than he otherwise could; and amongst the advantages of this not the least would be that he could keep weakly animals separate from the lustier and stronger ones, so that the poorer would have liberty to feed at will; a liberty which the selfishness of the stronger animal does not, as a rule, accord—and this greatly to the detriment of the poorer and weaker stock. Mixed herds of cattle and flocks of sheep can never be managed with the same precision as those carefully selected and classified. And it is just another of the advantages of the change of pasture system that if it does not in a measure compel the grazier to classify his stock, it greatly facilitates this process.

Area and Extent of Grazing Fields.

The number as well as the extent or surface of the different fields will be dependent upon circumstances. This will in large measure depend upon the area or extent of the fields; for if the grazier begins with a minimum, say, of four, and ends with a maximum of ten acres to a field, he will have, with a farm of equal extent on the whole, a greater number of fields than the grazier who begins with a minimum of ten and ends with a maximum of twenty to twenty-two or -four. But whatever be the number of the fields the grazier has at command, the system we are now considering demands that this number be divided into certain classes. Each class of pasture will have the number of the fields distributed, of course, by the size of the farm in the first place, and by the extent or area of its fields in the second; thus each class may have only one field, or it may have two or more. Of these classes, all of which are essential to the system of change of pasture, on which, as we maintain, the efficient economy of grazing depends, the first is that devoted to the land at rest—that is, in which the grasses are recovering from having been eaten off: this class we call "free or growing land," or, giving it a numerical distinctive number, 1. The next class is simply a field or fields of the first class which are ready for being stocked or fed off, which is done only by the best and most advanced cattle. This we call the "first feeding land," or No. 2. The third class is simply No. 2, which, being fed down to a certain and a poorer point, is fitted for the reception of the cattle next in quality or which are fed up to a certain point. This we call "second feeding land," or No. 3. The fourth class is for young stock or poor store cattle, and is simply the class No. 3 which has been still further eaten down by the second-class cattle. Or it may be some special extent of grazing land, giving but poor pasture, not easily, if capable of being at all improved. This fourth class we call the "poor feeding land," or No. 4. Where the lands as a whole afford exceptionally rich pastures, a fifth class may be added, adopting a still higher degree of classification of the animals as regards their condition.

Succession of Grazing Fields in Use.

It will be observed that by this or a similar plan the system of feeding, like the line of a circle, is perpetually returning into itself. So far as the fields are concerned in relation to their classes, and so far as the animals are concerned, they are in a condition of continual advance: the young stock, beginning with No. 4 class, or No. 5 as the case may be, pass up and on to No. 3, when they assume the rank of second-class or second-best animals

THE SANITARY ARCHITECT.

The Principles and Practice of His Work, in Healthy House Arrangement and Construction.—Technical Points of Sewerage and Drainage, Ventilation, etc.

CHAPTER X.

On the subject of the mobility or capability of motion of the sewage matter of drains, we have, in continuation, to remark that, taking drains as they are, this mobility must be a characteristic of the sewage which is to be passed through them, before it will be so passed with the certain and assured rapidity demanded by the necessities of health. And the only agent available in giving to sewage this desired mobility is water.

On this point an eminent authority says: "It is quite obvious that it cannot matter in the least what pains are taken with the construction of the drain, so as to give it the form, the diameter, the fall, and so on, which scientific observation may show to be the most effectual; it is plain that all this must be useless, and that all the cost of making it must be entirely wasted, if it is not amply supplied with water. No drains can be efficient through which there do not flow currents of water. If in any particular case it be not practicable to cause a current of water to be constantly flowing through a drain, then contrivances must be adopted to cause currents to flow through it at regular and no distant intervals. Without a provision for this regular and abundant supply of water, drains not only fail to accomplish their object, but they become positively injurious. They generate and diffuse the very poison the formation of which it is their object to prevent. When the animal and vegetable matters contained in a drain are not regularly and completely washed away, they become stagnant; a deposit is gradually formed; the matters constituting this moist and semi-fluid deposit are placed under circumstances highly favourable to their decomposition."

Planning and Plans of Drainage Systems.

In carrying out a system of house drainage which will yield the highest sanitary efficiency of which it is capable, there are certain points to which it is essentially necessary to attend; in succeeding paragraphs those points constituting what we may call the standard of perfection in the practical work of drainage will be stated, and each will thereafter be considered in detail. But before beginning the actual work of construction of the drains and their appliances, embraced in the system adopted, the sanitary builder has a very important duty to fulfil—namely, to decide beforehand what the details of that system are to be. In other words, he must consider the plan or design of the drainage. This we conceive to be one of the most important, as it is obviously the first, of the duties of the sanitary builder or architect. Yet, obvious as is its importance, it is by no means a satisfactory matter for consideration to know that in a great many cases there is no plan of the drainage of house property ever thought of apparently, certainly no design so committed to paper as the result of careful study of the circumstances which deserves the name of a plan. Very often, indeed, the drainage of a house is the last thing thought of; hence, when it comes to be forced, so to say, upon the attention of the builder (and this is often towards the completion of the general building), he finds that its condition compels him to adopt a plan of laying of the drains which is the very worst possible to be used, and which gives rise to grave evils afterwards. This seems to be the reason why such systems of house drainage so often met have arisen; for unless compelled to adopt them—either this or to have no drainage at all—one would have a difficulty in conceiving that practical men, or those who are called such, could possibly have devised and carried out a system so radically bad that a worse could scarcely be achieved. A builder, by neglecting in the very first instance to plan or design drainage of a property he is called upon to construct, may find that his building has been so far erected as to give him only one way of laying down his drains—in fact, "Hobson's choice, this or none,"—and, as we have hinted, the "this" will be but little better in a sanitary point of view than the "none." The truth is that it not seldom happens (so crooked, so to say, have been the notions of some builders as to what drainage really is), that after great expense has been gone to to carry out what was called a system of it, the result has been so grave in its evils, that experts have declared it would have been better, at least it could not have been worse, had no system at all been attempted.

It seems to us, therefore, imperative that the builder or architect should do what in all sincerity we greatly regret is neglected by too many of them, and this is to give the most earnest consideration to the *plan* of the drainage work, so that the drains shall be laid in the best places, the most easily accessible, and above all, as an essential feature of the system, that the shortest possible length of any part of the system of drains be near to or in immediate connexion with the house. A careful inspection of the ground or site should be made, accurate levels and measurements taken, and a block plan prepared, devoted to the showing of the drainage system only. On this the position and direction of all the drains should be shown, their sizes and all junctions marked, the depths at which the tubes are laid within certain equal distances named, the fall or inclination generally stated, the position of all "traps" indicated; so that at any future time, should occasion require, a glance at this, what we may call the "drainage block plan," will intimate at once the

position of the part of the drain which it may be desirable to inspect. This done, the builder or architect will not come under the censure of experts, as too many have done, for having designed a house the drains of which "are to be found no one knows where."

A plan such as the above, if accompanied with a schedule of facts, data, and prices of all practical kinds, would be all the more valuable, and be of exceeding service to the builder or contractor, who would no longer have perpetually to be asking the architect on his appearance "on the grounds" where this drain is to be laid, what is to be the fall, etc., etc., or, failing his bothering the architect, who apparently may not wish to be bothered "about such trifles," doing what he likes in the matter, which is not always what ought to be done. But for doing this the contractor can scarcely be blamed, as certainly it does not fall in any way within the line of his duty to plan and design. Moreover, this plan would be a source of satisfaction to the owner or tenant, inasmuch as by its very existence security would be given that so important a matter had by the architect been at the least thought over and carefully planned. A very marked contrast this to the system at present so much followed, where a few *verbal* directions are given, not always remembered by the contractor in his book of work, or if remembered not always clearly understood.

General Rules in Planning House Drainage.

The rules are good ones in planning house drainage to have the drains placed so that the sewage will be taken as speedily as possible from the house, not allowed to come in contact with it, further than is demanded by the necessities of the case; and to carefully avoid laying the drains *under any part* of it, more especially in the case of apartments. This, no doubt, is often extremely difficult to do, from the fact that, as all the main sewers are in the front street or road, whilst the kitchen and working apartments, water-closet, etc., are, as a rule, at the back of the house, to carry the sewage from these apartments to the street sewer the drains must be laid across and under the house in order to reach there. But even this difficulty can be got over—has been got over, and we deem it so essential to be got over for the interests mentioned that even extra expense must not be grudged to avoid the danger we have referred to. The most obvious way to get over the difficulty is to have a subsidiary sewer down the back of the range of houses, into which all the sewers or drain tubes are led. This subsidiary sewer is carried on till a cross sewer is reached, when it joins the main sewer, or is laid down the cross street till the main drain in the principal road is met with, when the junction is made. In detached or semi-detached houses the difficulty is not so great, as the drains may be led along the back and round the ends to meet the main sewer in front street or roadway; and in short blocks of houses a sub-sewer or larger drain may be placed in the back yards, or gardens, or "greens" as they are termed in Scotland, which should communicate with the street sewer, and which sub-sewer will receive the smaller drains directly from the back of the houses. In the "flat system" of building houses, so extensively used in Scotland, and, as will be seen from another section, the extension or introduction of which into England is being strongly advocated by some, the danger of leading the drains through and under the houses is not so great, inasmuch as there is generally, or very frequently, a passage between the houses leading from the front to the back premises in which the drains may be laid. And as there are facilities for thoroughly ventilating the passage, as well as the drains, any escaping gases through defects in the drain (which defects should not, however, be now tolerated) can be swept away as soon as created. But in regular street houses, as often planned, there is no other way of carrying the back house sewage to the street save by passing through the houses; hence, to avoid this evil, the system has been advocated of having the main sewer placed at the back of the streets between the rows of houses. However carried out, or whatever be the plan adopted, it ought to be borne in mind that the more perfectly the drains are isolated, and the shorter the lengths which may be near to or in contact with the houses, the more completely will the system of drainage approach the proper standard to be arrived at. Absolute isolation is impossible; hence the necessity to see all the precautions taken we have as yet hinted at, in order to have the drains themselves constructed as perfectly as they can be.

Principal Points to be attended to in the Practical Construction of Drains.

Having, in the preceding chapter, discussed the leading points connected with the first of the four divisions of the practical work to be done in connection with house drainage—namely, that connected with the position or plan of the drains of a house or other building property, we now proceed to consider those points concerned with the practical construction of drains. To this, the most important division of the subject, we direct the earnest attention of the reader.

In considering the points of material, shape or form, and of size or dimensions, in the threefold relation to house drains, it is necessary to note what are, or should be, the characteristics of a perfect drain, or as perfect a drain as can be obtained under the concomitant circumstances which characterise all work of this kind. What is necessary to constitute what might be called the standard or gauge of per-

fection may be thus stated. First, a *material* sound enough to be durable, strong enough to resist all pressure, of whatever kind, to which it is likely to be subjected, and impervious or solid enough to retain within its bounds all liquid matter delivered to it—so as to prevent all passage of liquid from the interior of the drain to the soil in which it is constructed or laid; further, the material must be such that when the separate parts constituting the drain as a whole are put together, its interior surface will be smooth and uniform, possessing a perfect freedom from all roughness or protuberating parts. The second point in the standard of perfection of a drain is, that its *shape* or sectional *form* shall be such as shall aid the rapid flow of the liquid along the drain, so that the maximum of length of flow will be secured in the minimum of time. Third, that the *size* or *dimensions* be proportioned—at least, bear as close a relation as is possible in general practice—to the volume of liquid to be passed through the drain. Fourth, that the *place* or *position* of the drain *in situ*, or in the ground, shall be such that the flow of the liquid through it be accelerated as much as possible by the action of gravitation,—in other words, the laying of the drains. This point, which is obviously most closely connected with the two preceding points already noticed, is obtained by giving the drain throughout its length a certain degree of inclination or declivity, this being technically termed the "fall" of the drain. The fifth and last point of the standard of perfection in the construction of house drains is, that the drains shall be properly connected with the house, all *junctions* carefully made, no matter whether those connections are in relation with one length of drain to another, or to the main or intercepting sewer, or to the house or soil pipes leading from or connected with the points of delivery of liquid refuse in the house, such as the sink or slop-stone in the kitchen or scullery, the bath, or the water-closet. All these points in the standard of perfection in the construction and laying down of the drains come under what may be called the hydraulic department of the art of house drainage, being concerned with the treatment of a liquid material in substance. The points connected with the treatment of the other product of house and trade refuse—namely, its gaseous emanations—come under the pneumatic department of the art, and will be named in a succeeding chapter.

Practical Points connected with Drainage Materials used in Construction of Drains.

Taking up the points in the standard of perfection of house drainage in the order in which we have named them in the preceding paragraph, that connected with the material of which the drains are formed will first engage our attention. For a long period, as we have already hinted at in preceding chapter, the points connected with this division of the subject, and also in relation to form or shape of the drain, which is so closely dependent upon the materials employed, the work of drainage was subjected to the most empirical rules—if this term can with truth be applied to a practice in which all rule seemed to be ignored, everything being left to the caprice, generally to the grossest ignorance of principles at all based upon true science. Now, however, the department has been taken out of the hands of men who trusted to rule-of-thumb practice, if they trusted to anything which could be called a fixed or definite practice at all, and it has been taken up by men of high scientific attainments. These have established a system based upon science, and this has been given such wide circulation, that if faults in house drainage practice are committed, they are at least perpetrated in defiance of all the indications of advanced science, which house drainage now is. But, great as have been the improvements in the practice of the art of making house drains, our readers will, from what we have already said, have concluded that greater improvements have yet to be made. While it is no less true that with a large body of those actually engaged in house construction, and necessarily concerned with its drainage, the merest rudimentary knowledge of the true science of the art has as yet been taken up, and even this scanty knowledge is often most improperly applied, amongst others (let us hope, constituting a smaller and a daily decreasing class) even this rudimentary knowledge is absent, and they go on even yet perpetrating all the blunders and making in their practice continually those mistakes which have brought down such undeserved odium upon sanitation as a science, and specially of that department of it which is now engaging our attention.

In describing, in a preceding chapter, the two eras of the history of house drainage, we stated generally that the latest era or system—namely, that in which the drains were closed or subterranean, and the great vehicle for the removal of their contents, water—was characterised by two epochs of practice. First, that in which the drains were universally constructed of brick or stone; and second, that (this being the advanced practice of the present day) in which the house drains are either circular, elliptical or egg-shaped in section. Those drains are, in fact, tubes or pipes, and are made of earthenware hard burnt, and more or less glazed and smooth, both in their internal and external surfaces. These, now everywhere known as "drain tubes," have, to a very large extent, superseded the old drains made of bricks, and greatly to the advantage of the drainage system.

THE WORKMAN AS A TECHNICAL STUDENT.

How to Study, and What to Study.

CHAPTER XV.

In continuing our remarks on some points connected with the study of arithmetic, we say that it would be comparatively of no great moment if there were given the acquirement of a habit of doing complicated sums, which might have a brilliant effect at an examination, and add to the "results" which "passing standards" generally bring out. For the time is really wasted in so far as this,—that those complicated and apparently difficult sums to do, have in a vastly too great number of cases not the slightest connection with, or practical usefulness as bearing upon, the actual work by which the pupils have in after life to earn their living. This waste of time is bad enough, and it is practically nothing else than waste, as it leaves within a month or two after school is left a mere residuum of knowledge; for we venture to say that this is the practical result of such work at school in a great majority of instances. But bad as this is, it is, as we have said, comparatively nothing to the more pernicious evil but too often attendant upon it. One would have little to say against the system which devotes days to getting pupils to execute brilliant performances with complicated figures, which, however little practical value they possessed so far as the pupil was concerned, were at least understood thoroughly. But of how many of the unfortunate pupils who are painfully crammed with such information it can be said that they know the "reason why" they do certain things, let those say who have had some practical experience in teaching, or a knowledge of the condition in which pupils leave school, and that some time more or less considerable after they have left its teachings.

Close Practical Bearing of Remarks in the Preceding Paragraphs on the Subject of Technical or Industrial Study.

The closely practical bearing of all we have given in the preceding paragraphs on the actual work of the technical student will, we trust, be obvious. If in any degree we have shown how essential a thing it is to cultivate the habit of thinking what his work or study is, and of giving earnest attention to the application in all cases, however apparently simple, we shall be amply repaid for what trouble we have had in presenting the results of our observation to him, and for the anxiety we have that he should earnestly address himself to what is, in truth, the great work of his life, and upon which so much of its success depends. It is not that many are incapable of giving thought—that is not the difficulty to be met. The first thing with many is to become convinced of the fact that there is any good to be had by thinking at all. They seem to get on pretty well without it, and know many just as apparently lucky. The "pretty well" may not be disputed, but they scarcely ever deny that they know of many who do get on vastly better than they do, succeed remarkably well, and attain to positions of comfort—some of positive wealth and eminence—to which they confess they have not the slightest chance of attaining. They fail to see that it is primarily to their lack of thinking that this comparatively—it is often positively—poor position they occupy is due. It may be accepted as a rule, having but very few exceptions, that the men who have got on have been those who have thought and, indeed, never cease to think. "I am not paid for thinking!" or something to the same effect, has not seldom been said to employers by their workmen. They unfortunately for themselves forget that it is just thinking which *would* pay them, whether as workmen or as employers of workmen. Indeed, of this workmen may rest assured,—that without thinking, they will have but poor chances of becoming employers. And to this point we should at least have the ambition or desire to attain, even though the actual attainment may seem very likely to be exceedingly remote. It is at all events better to aim at high game, even should something less valuable be brought down.

Thinkers and Workers—Theory and Practice.

And here, as it will have a practical bearing upon our general subject, we shall in a sentence or two glance at what is often talked about, but not always understood clearly—namely, the position, the relative position, of thinkers and workers—that is, the men who plan and design work, and those who carry out and realise in practice the plans and designs. The class of workers in point of numbers far outweighs in importance that of the thinkers, and this from the nature of things must be so, as it naturally requires the assistance of many more to carry out a plan or design than are required to conceive and prepare it. Thus one man can, and often does, design a machine or a structure, which to give practical shape and form to will demand the labour, and that possibly for a great length of time, of many workmen. The thinker and the worker may, of course, be combined in one man (indeed, not seldom are), and when the happy combination is met with, so also do we, as a rule, meet with one or other of those instances which Dr. Smiles has so graphically described in his well-known accounts of self-made men, in which the possessor has risen to the highest position in his profession. But for many and very obvious reasons the thinkers and workers form distinct classes, and, as already stated, the latter vastly outnumber the former.

Hitherto, as the rule, and indeed now to a very great extent, there has been antagonism between the two classes of men. This with many of the workers is really more a matter of sentiment and feeling than of

positive dislike. But it has taken, and still not seldom takes position in the minds of many in the latter way, giving rise to actions on the part of the workers which have been very damaging to the material interests of the nation. Many of those so indulging have yet to learn, we fear, that it has been and is as damaging to themselves, individually much more so. Be this as it may, we should point out most earnestly that this antagonism between the thinkers and the workers should be sternly denounced, and its manifestations as decidedly put down when displayed.

In place of their being antagonistic to each other, as many, unfortunately, think, they are in reality bound up in the closest tie of a common interest. The one could not exist without the other. For it is only in exceptionally extreme cases that the combination of the thinker, the designer, and the worker, the executor of the design, is met with in one man. And in this case, be it remembered, one man's work only can be done. And it is obvious that, if the designers were in all cases the executors, the amount of work done throughout the country would be reduced to a minimum. In nearly every case, then, the workers exceed of necessity the designers, and in those of constructions of great extent the workmen outnumber them by hundreds. But the designers would thus be helpless in getting their plans carried out without the assistance of the workers, and the workers, on the other hand, would be helpless without the thinkers. For without the result of their thought in the plans from which they work, what could the workers do? They would necessarily be powerless to complete what special work happened to be required.

We do not assert, what would in many instances be easily shown to be wrong, that amongst the workers there would not be some who could design or carry out the plan of any work in question. These might and would be more or less numerous. But here again we come back to the same point we have started from; for this worker who had the ability to design would wait in vain to see it realised in actual construction, if he failed to find the army, so to say, of workers required for the labours of execution. And of the great bulk of these it may be safely asserted, and without fear of contradiction, at least of refutation—for it is one thing to deny or contradict and another to refute—that the unskilled and ignorant vastly outnumber the skilled and the educated. It has ever been so, and unless human nature and the conditions of human existence greatly or wholly alter, it will ever be so.

And if there be any distinction to be made between the two classes, as to which is the more important, there cannot be any doubt in deciding that the thinker is more valuable than the worker; for the work could have no existence without the thought. But, as we have said, the two are thoroughly dependent upon each other, and it is not only the absolute truth, but is the more wisely charitable mode of settling this question, to say that the one cannot exist without the other in all cases where the work to be done in carrying out a design requires the assistance of more than one man, who ought in himself to combine the ability to design with the skill to construct. And cases of this kind infinitely outweigh in number those in which the designers require only themselves or the help of but a few to have their plans completed.

This antagonism as between the class of the thinkers and that of the workers has been carelessly and thoughtlessly fostered by the action of certain of our public men. Indeed, looking at the higher and material interests involved, we should be inclined to use stronger terms than those implying want of care or thought. We could point to not a few instances in which the relation between the two great classes we are now considering has been placed by public men in an altogether false light,—a light calculated to increase the difficulties which exist, unfortunately for our true national interests, amongst us in relation to work and labour (using these terms as including both thinkers and workers, for both have in their respective spheres to work, and work earnestly). We remember on a somewhat celebrated occasion a great public speaker, who for purposes or aims which he himself could have best explained, but which, however, he left to be guessed at by his audience, indulged with glowing language in a splendid glorification of what the mere hands, the brute force or animal labour of the workers could do, and the general works which they executed. And in illustration he pointed with all due oratorical effect to a fine piece of engineering work in the neighbourhood of the hall in which he spoke, as a striking example of the truth of his remarks, asking, with what he himself claimed to be a pardonable pride, where the work would have been had not the workers been there. But while this could not be disputed as opposed to truth, it was not the whole truth; indeed, strictly speaking, it was not the truth at all. There is in reality no such a thing as half truth: a thing can only be complete when the whole is considered; and, to quote a well-known illustration, the play of *Hamlet* is not the play in reality if the Dane be left out. The illustration of the oration, complete as it was, gave a totally false, and, from the grander and higher point of view, a fatal impression of the position as it actually was. He failed, and we fear purposely failed, to point out to his admiring audience that, while the labourers were highly to be praised, the work could not possibly have existed without the exercise of the thought of the designer of the splendid structure he so highly praised as being the work,

and the work only, of the mere labourers. And this "thought," be it remembered, did not originate and end only with the engineer or architect who planned or designed the structure. It permeated, so to say, throughout the whole work, down to the very lowest grade of actual labour done in carrying it out. From the architect or engineer to his assistants, from the resident engineer or clerk of works, from the foremen of each class of work, down to the ganger or overlooker of each class of labour, thought at every stage was observable. And if at any time that thought had been suspended, although exercised by a few in number, the mere labourers, the "hewers of wood and drawers of water," so to say, might have thrown down their implements and tools in despair, for they would have found without the directing "heads" that their "hands" were in helpless impotency. Let the reader, to whatever class he belongs, rest assured that as in his own existence as an individual, in which both physical and mental faculties and capabilities are ever present, so in the "body politic and social," the hand cannot say to the head, "Of what use art thou without me?" nor can the head say to the hand, "I do not need thy help." Very powerless and useless would the one be without the other; as powerless would our workers and our thinkers. Those considerations, and others which flow naturally and inevitably from them, are not, as some of our readers may conceive, foreign to the subject of our paper. On the contrary, they have the closest bearing upon it, as will be readily enough perceived if thought be given to it. And it is precisely the giving or the not giving of "thought" to work which constitutes the difference between the successful technical student and him who is but a student in name, and not in effective and useful work. Let the reader think this carefully out, and he will see the full force of what is here stated. We return, after this practically useful digression, to our subject.

Foregoing Considerations applicable to all Branches of Technical Study.—Arithmetical Studies.

The principle we have enunciated as to careful thought being given to reading as a branch of study applies to every department of it in which the technical student may be interested, and without its strictly-carried-out enforcement such study will bear little—indeed, no practical fruit. It applies, therefore, to what is considered to be only an elementary, and too often lightly-thought-of branch of education, such as reading and arithmetic. We have dwelt upon the all-important matter of thoughtful reading; we have said something also of its application to the other elementary or primary part of education—arithmetic. We have still something to say concerning this, and more particularly as to its bearing upon the advanced work of mathematics, which are of essential service to all branches of technical work in which the mechanics of construction are involved. If reading ought to be conducted with thoughtful care, so that each step taken in it be so thoroughly understood that sure ground, so to phrase it, will be obtained for the making of further and sure progress, it is not of less but in another sense of much greater importance in the study of arithmetic. It is, we admit, quite possible for arithmetic to be learned in such a way that a pupil will leave the school or class with a capability of doing certain "sums," as they are called, and some of them even of an elaborate or complicated character, and yet have not the slightest intellectual conception of what the work really is. "Learning" in this sense is but a name only, and that it comprises all that constitutes the knowledge of a vast number of pupils is but too well known to those who have had much to do with school and class work. The rules can be said or repeated glibly or readily enough, examples can be made out with all due facility; but what the rule is, what is its exact meaning, how it gives life, so to say, to the work based on it, the pupil has, but too frequently no conception of. Just as he may have "learned" by heart a grammatical rule and all its examples, and can repeat them with unfailing accuracy, yet knowing no true connection between the rule and the example, there has been no learning by the intellect. This has not as yet got so prominent a place in the technical language of teaching as the everywhere-known expression, "learning by heart." And yet it is only the learning by intellect that constitutes true learning. It is scarcely necessary, therefore, to say that the reader, anxious to make a knowledge of the higher branches of mental sciences, such as mathematics, practically useful to him in his daily work, must thoroughly—that is, intellectually—understand all the rules of arithmetic. Each one must be so understood before a succeeding one is taken up; for each depends upon the other, and the whole constitute the very basis of higher work in this class of mathematics. But something more than understanding the rules is required. The utmost care is demanded in the practical working of them out, so that no single element in the combination is left out. In no sciences is the value of "little things" more clearly shown than in those of arithmetic and mathematics. The omission of the veriest trifle vitiates and destroys the accuracy and value of the whole. Each computation or calculation may be regarded as a chain, of which if but a link is wanting, the chain for all practical purposes is useless. It does not, in fact, exist; for a chain is really so only when all its links are complete. And its strength lies really in its weakest part. In the chain of arithmetical computations or of mathematical calculations there must be no weak parts.

THE FARMER AS A TECHNICAL WORKMAN.

His Tools, Implements, Machines and Materials.—The Principles of his Work in its Various Departments.

CHAPTER XI.

In treating of the classification of soils, we referred at conclusion of last chapter to the variety of soils met with in the range even of very limited districts. But still more decided, and still more puzzling to the scientific agriculturist as introducing disturbing elements in his calculation, is the diversity of soil even in one field, and this often in cases where the field may be of comparatively, not seldom of absolutely limited extent. And as different soils require different treatment, both mechanically and chemically or manurially, as each class differs in its physical and its chemical characteristics, the reader will perceive with what disturbing elements the practical farmer and the scientific agriculturist may have to deal, even in a farm of but limited extent, but in which diversities of soil are met with.

In taking up the points connected with the soil we shall consider it in the following twofold aspect. First, as being a medium in which plants can be grown, and a vehicle by which the fertilising constituents on which their development depends is conveyed to them; the fertilising constituents here referred to being supposed to be present first naturally in the soil, or secondly, given to it by the addition of manurial substances, or thirdly, those fertilisers which are obtained through the medium of what are known as the atmospheric influences. Thus, the first aspect in which we shall view the soil is that which includes all points bearing upon its physical or mechanical condition, and those operations of farming by which that condition is influenced, changed or modified in character. The second aspect or point of view from which we shall consider the soil is that of a medium in which there is stored up, so to say, or there are present in it, in varying number and quality, those constituents which, when taken up by the plants, fertilise them and aid their development. This, the second aspect, is that which includes all points bearing upon the chemistry of the soil and of the plants which grow upon it.

Taking up, then, the first of these aspects of soil, considered as a medium in which plants can be grown, and as a vehicle by which their fertilisers are conveyed to them, we come at once to the physical or mechanical condition best suited to give the plants the highest chance of production or fruitful development. At first sight it may not be easily understood by our readers how the mere condition in which the soil is can exercise any influence upon the way in which the plants can be fertilised; or in other words, and in the converse, how the mere mechanical condition in which it is exercises an important influence upon its fertility. Suffice it here for the present to say that the difference—the mechanical, the physical—between two soils is often that which constitutes the difference between their agricultural value, that is, their crop-bearing value. This mechanical condition desiderated is indicated by the fineness with which the soil is worked, pulverised, or comminuted, or, to use the technical expression, by the fineness of its "tilth." Two soils have been carefully analysed, and shown to be of the same value, and yet there was a marked difference between them in the fertilising, that is, agricultural value; the better of the two in this respect owing its increased value simply to its mechanical condition, this being fairly pulverised—that is, in technical language, well worked and weathered. A well opened up and finely pulverised soil not only admits of the atmospheric influences acting most favourably upon its pulverised mass, but its temperature is higher than when it is allowed to remain in a condition opposite to this—that is, close and impervious. The difference in temperature between two soils may often, indeed, be made evident by the mere handling of them. A light soil well pulverised will feel warm, yet moist; a heavy soil unworked will be cold and dry; and the mere mechanical condition will be still more easily noticed—the one being friable, easily crumbled by the pressure of the hand, the other hard, tenacious, and adhesive. It takes but a very trifling knowledge of the habits of plants to enable one to decide that there must be a great difference in their growth and development in the two soils, one being so much better fitted to aid this than the other. And this difference in temperature—the higher temperature being obviously more favourable to plant development than the lower—is not dependent upon the absolute amount of water or moisture which the soils carry or contain in their bulk. For a heavy clay, which will take up and retain a much greater volume of water than a lighter soil, will be the first, nevertheless, to suffer from drought; while the lighter one, the best worked soil, will be the moister in a season of great dryness. When we come to the practical working of soils we shall see how these general results are obtained, and what are the influences which modify them more or less.

Special Features of Soils in Relation to Plants.

Meanwhile we proceed to notice the other special points or features of soils. All plants are made up of two parts, called the organic and inorganic. The organic part is also known as the combustible; being capable, either by the agency of active fire, or by the slower, yet in time equally effective natural combustion, of oxygenation and decay, of being resolved into its original elements and wholly disappearing. The

inorganic parts of all plants, otherwise named the "mineral constituents" or elements, are found present in what is called the "ash" of the plant, left after the organic elements are consumed or burned. The ash of a plant is thus also called the incombustible constituents.

The ash or the mineral or inorganic or incombustible constituents bears a very small proportion indeed to the organic or combustible elements of the plant. Thus, in the cereal or grain crops of the farm, we find that in 100 lb. of wheat grain there is only 1·6 lb. of ash or inorganic substances—almost the whole of the weight or bulk being taken up by the organic or combustible elements of the plant. It will be useful here to note the proportions of ash or inorganic to the organic elements of the leading crops of the farm. Thus, in 100 lb. of the grain of barley there are only 2·34 lb., in oats 2·90, rye 1·36; Indian corn or "maize"—or simply "corn," as it is invariably called in the United States, where it is a very important crop—has the highest percentage of ash, showing 4·40 lb. for each 100 lb. of the plant. While the above shows the proportion of ash or inorganic constituents to the organic in the *grains* of the cereals, the following shows the percentage in the *straws*. Thus, in 100 lb. of wheat straw there are 5·10 lb. of ash, in 100 lb. of barley straw 5 36 lb., 100 lb. of oat straw give 5·10 lb. of ash. Rye straw yields 4·10, and Indian corn 4·40 lb.

Taking now the leguminous plants of the farm, by which names beans, pease, vetches and lentils are known, we find that 100 lb. of beans yield 4 lb. of ash, pease 3·00, vetches 2·40, lentils 2·06. Of the plants chiefly grown for industrial or trade purposes, as flax for its fibre and for its seed (known as linseed or lintseed), the following show the proportions of ash in 100 lb. of the plant or fibre and of the seed respectively. Thus, 100 lb. of flax plant yield 6·05 of ash, of linseed 4·63; hemp plant or fibre 6·37, and hemp seed 5·60.

Coming now to the "root crops"—by which name, as also sometimes by that of "green crops," the turnips, mangold-wurtzel, carrots and potatoes are known—we find in 100 lb. of turnips, bulbs or roots, 0·78 lb., in mangold bulbs 0·88, carrots (roots) 0·91, potatoes 0·76, Jerusalem artichokes (a valuable feeding crop, not nearly so extensively cultivated as they ought to be) 6 lb. of ash.

The "ash" of plants in the inorganic constituents varies, as may be supposed, or is itself made up of various constituents, which are all derived from the soil. This fact is in measure indicated by the name 'mineral" constituents, by which they are frequently distinguished. These mineral constituents are present in soils in varying qualities and number; some soils have some elements in excess, some are deficient, while others are almost totally deprived of them. The mineral constituents present in soils are chiefly silica, iron, lime, magnesia, potash, soda, phosphoric, sulphuric and carbonic acids, and the chlorides of sodium and potassium. Those constituents vary with different plants, both in number and in the percentage they bear to the whole plant; thus the farm crops are often distinguished in agricultural science according to the mineral constituent they chiefly take from the soil—as a silica plant, a lime plant, and the like. But the mineral constituents required, so to say, by the plant must be present in the soil, or, if absent, must be added to it in the form of manure. But they may be present in the soil, and in sufficient abundance for the necessities of the plant, and yet, from the circumstances of soil condition or preparation, or of plant culture, the plants may not readily assimilate or take up, or may not be able to reach the supply of mineral constituents in the soil. When we come to the specific points in the practical working of the soil and its treatment in manuring, we shall see how this results. Meanwhile, as bearing closely upon the subject of soils in relation to crops and cropping, we here, as indicative of the variety of mineral constituents present in soils, and how much they are drawn upon by the plants grown in or upon them, have prepared the following table, showing the proportion of constituents which the produce of different crops per acre withdraw from the soil. In reading the table the reader will please to note that the percentage of constituents withdrawn from the soil by the different crops are estimated from the following data. In the case of the wheat (1), taking the crop or yield per acre at 25 bushels, and the weight of the grain per bushel at 60 lb., we have 1500 lb. of grain per acre. Calculating the weight of the straw of this amount of grain at twice its weight, or 3000 lb., taking also the percentage of ash in the grain at 2 per cent., we have 30 lb. for the weight of its ash; and taking the percentage of ash of the straw at 6 per cent., we have 180 lb.: in all, grain ash 30, straw ash 180 = 210 lb. of ash carried off by the whole crop, and which is made up as we see in the table. In the case of the barley crop (2) we have 213·3 lb. of ash to deal with, carried off by the crop estimated at 48 bushels at 55 lb. per bushel; the grain weighing 2640, the straw 3300 lb. In the case of the oat (3) we have 198·9 lb. of ash to deal with, taken off by the crop of 48 bushels per acre at 42 lb. to the bushel, giving of grain 2016 lb., and of straw 3024 lb. In the case of the Indian corn (4) we have 167·5 lb. of ash to deal with, derived from 2280 lb. of grain per acre, 625 lb. of pith of the cob or head, 2449 lb. in straw and leaves. The analyses of the other crops named in the table, such as rye, beans, etc., show the percentage of each constituent in 100 parts of the crop, plant or seed.

	(1) Wheat lb.	(2) Barley lb.	(3) Oats lb.	(4) Indian Corn lb.	(5) Rye (grain) in 100 parts.	(6) Rye (straw) in 100.	(7) Beans in 100.	(8) Peas in 100.	(9) Turnips in 100.	(10) Potato in 100.	(11) Cabbage	(12) Meadow Hay.	(13) Clover.
Potash	29·59	38·3	36·5	—	22·08	17·36	24·50	36·67	41·96	52·88	11·70	18·11	31·73
Soda	3·02	2·6	3·6	—	11·67	0·31	2·85	7·32	5·09	2·85	20·42	1·35	0·67
Lime	12·94	15·6	12·0	13·5	4·93	9·06	32·83	5·39	13·60	0·63	20·97	22·95	32·80
Magnesia	10·52	8·8	9·1	12·4	10·35	2·41	3·84	8·62	5·34	3·52	5·94	6·75	8·40
Peroxide of Iron	ox. 2·55	1·6	2·7	3·0	ox. 1·36	1·36	3·44	1·00	—	0·32	0·60	1·69	0·40
Phosphoric Acid	20·56	24·3	22·3	31·4	49·55	3·82	5·75	30·88	7·58	7·76	12·37	5·97	8·40
Sulphuric Acid	10·56	4·3	5·8	6·4	0·98	0·83	2·83	4·43	13·60	11·38	21·48	2·70	3·30
Chlorine	1·97	—	—	—	—	—	—	—	3·60	4·01	5·77	2·59	7·20
Silica	118·29	107·2	96·8	36·4	0·43	64·50	3·96	Silicic acid	7·95	2·86	0·75	37·89	Silicic acid
Chloride of Potassium	—	0·6	3·8	—	—	—	1·36	0·52	—	—	—	—	7·07
" Sodium	—	7·0	6·3	3·0	—	—	1·89	2·17	—	—	—	—	—
Carbonic Acid	—	—	—	3·8	—	—	—	—	—	22·13	—	—	—
	210·00	213·3	198·9	167·5	—	—	—	—	—	—	—	—	—

Relation of Plants to the Fertilising Constituents in the Soil.

From what we have thus given on the subject of plants containing mineral or ash constituents, and deriving these from the soil—this latter being considered simply as existing in its natural condition, and not as having anything added to it artificially by the labour of man—it will be seen that two very important points arise in connection with the general subject of soils and their treatment in relation to the crops grown upon them. Those points which we shall now take up are, first, seeing that the plants have, as it were, special wants for mineral constituents, and that each crop takes up and carries away with it so many of those constituents, each special plant necessity, so to say, taking away only certain special constituents. There must, therefore, be a close and special relation of the plants to the constituents present in the soil, and this somehow must have an influence upon plant culture. And the second point we have alluded to arises out of this relationship, and closely concerns the plants, in so far as their supply of this food derived from the soil is concerned. For if, as we have seen is the case, plants draw largely from the soil certain fertilising constituents, if a succession of crops be taken from the soil, each crop taking away from it so much of its own contained and original supply, it is a possible thing that a soil may be so drawn upon that its constituents—plant-food—may in time become exhausted, or practically so, so that the crops borne by it will be poor compared to what they would be if they had abundance of food in the soil. This last point brings us face to face with one of the most important questions connected with our soils, and which has, in the various scientific points which it presents, exercised to a great extent the minds of the majority of our agricultural writers in times but recently gone by, and is still to a large extent engaging their attention. This is the question of the exhaustion of our soils. The keenness with which its various points were discussed arose largely from the wide circulation given to the views of the celebrated German agricultural chemist, Baron Liebig. It is in no way prejudging the case to say that those views were extreme; and although they were advocated with all the literary ability, and backed with all the profound scientific knowledge of the great chemist—for he was in every sense this—we think he omitted to take into account, or at least to give them all the weight which they undoubtedly deserved—the influences and circumstances which greatly modified the deductions he drew from his investigations and researches. Baron Liebig held that the system of modern cultivation—and specially note- and blameworthy in this respect British farming—was eminently suicidal in its practice. While we had only a certain store, so to say, of fertilising constituents present in our soils, we were by our methods of cropping drawing from it continually, and if putting anything back to it by way of restoration, put practically so little that it merely retarded, but did not finally put off the evil day when we should find that we had a soil, but one so exhausted of its fertilising constituents that the crops we grew upon it would be so poor that we should find them practically of no value.

Mineral Constituents of Plants in the Soil.

We have said that all soils contain the ash or mineral constituents of all plants; but that they do not contain them all in equal quantities. But even if they all possessed the whole of the constituents necessary for plant development, and all in sufficient quantity to serve the plants grown upon it at the first beginning of the time when they were put under cropping, Liebig was quite correct in saying that a continuity of cropping must necessarily result in depriving the soil in course of time of all its fertilising constituents.

THE MACHINE MAKER OR GENERAL MACHINIST.

SPECIAL EXAMPLES OF HIS WORK—ITS LEADING TECHNICAL PRINCIPLES AND DETAILS.

CHAPTER VIII.

WE alluded at end of last chapter to the views so long held by practical machinists as to the materials they used in the construction of their machines, and the ignorance of many as to what the properties of these really were; but in continuation we have to say that this indeed was just one of the great advantages which resulted from the practice—which as time passed became more and more widely spread—of testing materials in order to obtain data by which their strength could be ascertained with some degree at least of approximative accuracy: namely, that it drew attention to the fact that while the users of machine construction materials of which the chief was iron acted practically upon the belief that all were of the same constructive value, the makers had the fact forced upon their attention that some of them at least had themselves no idea of what they were making. It might be—but too often was—of bad or indifferent constructive value; or it might be very good, which was often the case; but certain on one point in either case they were not. So that practically it came to this, that they had to sell to their customers what the materials they employed and the appliances they used gave them. What the processes were in reality some might guess at—many did not take the trouble to do this even—but few, if any, in the early times knew.

The result of all this new life of inquiry or investigation and experiment was that makers—iron masters, for example,—who were conscientiously desirous to give their customers the best materials they could purchase, so soon as it was clear by a wide, or pretty wide, range of experimental truths that materials varied very much, began to pay the closest attention to the processes by which they were produced. And the result of this honest determination showed—to use a word which, however, gives the lowest view of the matter—that its *policy* was sound. For those materials marked with or known by a particular "brand" took the market as the best, and for them the best prices were obtained. We may thus see the interdependence of one branch of industry upon another; and how the improved practice of one compelled or brought about that of another; forming the introduction of a new era, in which science gave its help to practice, while at the same time it did not consider it beneath its "dignity" to learn lessons from practice itself. We find thus that vast improvement in *all* the branches of constructive work took place, of which the nation is now reaping the immense advantages, and of certain of which, being those most directly interesting to our readers, many of the pages of the present work give a more or less detailed, but always practically useful, account.

Machine Science.—The Science of Modern Mechanical Work.

All this, which has been but briefly glanced at, space not being in our possession to give its details, all of which are however of the highest suggestive interest, led in time to the formation of what may be called the modern science of mechanics; or, more simply stated, machine science. Space does not permit us to enter into any detailed statement of the directions in which science, considered in its purely theoretical aspects, has been of late years working; and what has been effected in the way to which we have but just alluded, in raising, not merely the practical, but the theoretical status of nearly every branch of industrial art, more especially that of machine making. And this may with almost absolute truth be said to be the basis upon which all other industrial work is carried on, seeing that there are but few branches, if indeed there be one, which does not demand machines, or at least mechanical appliances, for the performance of its work. And however simple these may appear in some of the least important of our industrial arts, it is beyond dispute that, to give them the highest economical working value, the application of principles truly scientific is essential. For it is not, as some technical readers seem to think, that the largest and most imposing of our machines, or the most complicated of mechanical appliances, are those only which embody or demand for their design or construction the application of the highest range of scientific principles. A small machine may be a more remarkable illustration of the value of those principles, themselves based on natural laws or phenomena, than one vastly more ponderous, bulky, and in detail complicated. In this statement there is a principle involved of vital interest to the working machinist, which principle, along with others, will be explained in paragraphs to which we shall presently direct the attention of our readers, and which will concern themselves with some points to be considered by the working machinist as essentially vital to thorough success in his practical career as a designer and a maker of the wide variety of machines and mechanical appliances demanded by the still wider variety of industrial arts practised in this kingdom and in other countries.

If we take the wide variety of machines now in daily use, and especially if we direct our attention to those which, in certain important branches of our industrial arts, such as those of the textile manufactures (see the series of papers entitled "The Factory Worker"), have been designed for the express purpose of not merely supplementing, but of doing away with to as complete an extent as is practically possible

with the necessity of employing human or manual labour; we see in them such a variety of parts and such a complication of movements that at first sight, by one not practically connected with the work, it would be taken for granted that it would take, so to say, a lifetime to understand them, numerous and complicated as they are. But by observation and patient labour it would be discovered that certain parts and movements, however numerous in themselves, would fall under or be classified as constituting definite groups, other parts and movements falling under other groups, each group or class having definite characteristics marking it off sharply from its neighbour. The close observer would, moreover, perceive that in the linking together, so to say, of the mechanical connection of one group or member of a group with another, which constitutes a working machine, there was what might be called an overlapping in some instances of one group with another.

What we have here supposed to have been done by a close observer will, when the reader thinks of it, have constituted a great advance towards the formation of a science for machinery. All practical or inductive sciences are based first on the observation of and search for a wide variety of facts as they exist around us, of which, after accumulating a large number—and the larger the better—we find that we can reduce their apparently endless number, and reconcile what appears to be their conflicting and contradictory elements. Thus by classification or grouping we have made an important advance towards constituting a *science* of mechanism. Looking, indeed, at the meaning of the term here italicised, which involves the "knowing" of a thing, and as by this observation, classification, and grouping, we become acquainted with their peculiarities and characteristic differences—in common language, *know* them—it may be said that thus a science is practically founded. We may not know at first start much about each, but we have made a most practical advance towards obtaining a thorough knowledge of them when we have classified or reduced them into "order." For this alone gives a power of dealing in detail which is never possessed by him who takes up a confused heterogenous mass of materials which in their mere numbers are perplexing and thus are calculated to deter from rather than incite to the closer investigation of each which alone can give a true knowledge of what the whole of the objects are.

Value of Observing Facts and Grouping or Classifying them to the Practical Machinist.

We have supposed this preliminary work of closely observing and thereafter of grouping or classifying the parts and movements of machines to have been readily gone through by the observer, thus making the advance towards the formation of a science of machines, or "machine science," an easy matter comparatively. But in looking upon the past history of practical machinery and mechanics, it is essential for the reader to know that this work was so far from being readily done, was a matter of such slow growth, that it may be said to have been spread over a period, if not of centuries, at least of many generations. At all events, so long was it before the advance was made towards the formation of a science of machines, such as we have supposed the close observer making so readily and easily, that machine science is literally quite a new thing, a matter as but of a yesterday in the history of a people. Author after author took up the subject of what is generally termed "mechanics" under titles for long more or less fanciful, some so much so that the title gave little or no indication of what the book actually contained, or was concealed in the terms of a dead language, and as little likely to be then known to or by the "base mechanics" of the period as to the "intelligent artisan" of our own day. Those authors described what some would oddly call "no end" of machines—possible, and, as we have already said, impossible also; but in them all the same characteristic of prolonged and copiously detailed descriptions of part after part was observable. And if a book contained—as many books of those times did contain—a great number of illustrations of machines, as each machine had a number of parts, greater or fewer as the case might be—in all pretty numerous,—and further, as each part in each machine had to be described separately, some idea of the hard reading such works gave to those who took them up with an honest intention to peruse them, may be formed. But this was not all, nor, indeed, was it the point of the matter. For, so far from having any idea that there was a possibility, to say the least of it, of classifying the various parts of machines under different groups, the parts of the machines had no distinctive names such as we now know them by, and are given to them. Further, and as giving rise to a still greater complexity and a wider distance from a system or science, the very machines themselves had no distinctive names. Thus, as Professor Kennedy, in the very able and truly interesting, while practically suggestive paper, read before the Society of Arts, points out, if the machine described was what *we* call a "pump," it was gravely designated by those early authors as a "machine to lift water from a well by means of a man," or it might be called a "machine to lift water from a well by means of a water-wheel." As no definite name was given to a machine which had a definite purpose, each machine had to be named in long and roundabout terms, which were repeated again and again as often as the machine or a like machine had to be described. A crane or winch to raise a weight would be described under a different title, according as the object was to

elevate a weight, such as a stone, from the ground to the upper part of a building, or to raise a bucket full of coals from the bottom of a mine shaft—the object or purpose being generally part of the title. Titles, in all cases thus long, were often made much longer, and sometimes still more unintelligible—in others purposely obscure—by the introduction of grandiloquent words and phrases, giving that savour or flavour of the "marvellous" which we have seen to be so attractive to the early mechanical writers.

If, then, the machines themselves have not been classified or thrown into groups, to each of which the distinctive name once given was always thenceforth used, it need not be wondered at that the parts themselves of the machines were practically in the same condition of hopeless entanglement and confusion. Hence, no matter how frequently and fully the same part had been described before, it was described as fully wherever it made its appearance; and this on terms as scrupulously minute and detailed as if it had never been met with before, never before introduced to the notice of the reader. It is certainly difficult to conceive that those early writers in mechanics had failed to perceive that, as a machine was but an aggregation of parts, those parts would be again repeated as performing the same office, and might therefore very naturally be classed and thereafter always considered and treated of as coming invariably under one group. Nevertheless they failed to perceive it, or if they did take note of it, it in no wise influenced their system, if such a name can be given to a style of mechanical description which had none of the elements of a true system. Mechanical treatises of the early times only deserved the name in so far as they described machines; and this description being in no way based upon any intelligent system, was made up of a vain and endless repetition. And simple and effective for all the purposes of mechanical description and exposition as is the system we are now possessed of, for not only classifying the movements of machines under their own special and well-defined groups, but for giving and in all cases retaining definite names to definite parts, as a "crank," a "connecting-rod," a "cross head," a "lying" or "line shaft," a "clutch," a "pedestal," and so on,—it took, as we have seen, many, many years for such a system to be discovered and established. Such practical points as are of necessity involved in this system, which generally may be called Machine Science, are met with in the full consideration of the subject.

Special Points suggested by the Considerations named in the Preceding Paragraphs.

The point here alluded to is one which carries with it considerations of the utmost practical value to the machinist who is either beginning or is studying with a view to begin his actual practice or business of machine making—taking the last term to include here the branch of design as well. This special lesson or suggestive point, derived from a study of what constituted the features of the conditions in which the early machinists did their work, is this: That in order to make the progress, or, as we may put it in another way, to take the position they did, and to do the work which they actually produced, and which in its advanced stage formed the basis of our modern art of machine making, the early machinists brought to bear not one quality, but many qualities, which together constituted that mental power which enabled them to overcome difficulties and sweep away obstacles to progress which, when we look at them with all the knowledge we now possess, might well have been deemed by the early workers so insuperable as to have justified their giving up all attempts completely to overcome them as hopeless. And this is a very curious thing to consider: That while the early machinists not only overcame those difficulties which may be called the primary ones, or those which at first met them as they entered on the path of progress, each successful step forward was not the completion of their work, but in reality—and a very grim and grave reality it was to them—it but created another difficulty, which in time they had to overcome. So that it was long before they could say they had reached that point in the history of the art at which a true basis for its future had been established.

What the various qualities were which the early machinists brought to bear upon the great task they had to perform need not be named specifically in order here. They will best be pointed out and given special place to in the consideration of various points connected, and that in the closest of ways, with the practical education and training of "The Machine Maker or the General Machinist," which we may perhaps yet find space to present to our readers. In using this term it must be distinctly understood that by it we mean the machinist who is practically engaged in the everyday duties of what is called the "trade,"—in other words, the man who "has to work to live, and who to live has to work." This does not, however, exclude the technical reader who is learning what machine science is, for the reader may be a student and yet actually working at the bench or the lathe—"at work by day, at books by night." But the meaning we attach to the term machine maker or general machinist does exclude the reader who is *only* a student—this and nothing more. For, let it here be noted, that there is a tendency on the part of the mere student to look upon his course of study as ending only, and to decide that it ought legitimately to end only, in *knowing* its various details.

THE FACTORY OR MILL HAND AS A TECHNICAL WORKER.

THE ORGANISATION, GENERAL DUTIES, AND SPECIAL WORK OF THE STAFF OF FACTORIES FOR THE PRODUCTION OF SPUN AND WOVEN GOODS—THAT IS, "YARN" AND "CLOTH"—AND THOSE CHIEFLY IN COTTON AND WOOL.—GENERAL DESCRIPTION OF THE VARIOUS PROCESSES OF MANUFACTURE.

CHAPTER XVI.

Illustration and Description of the Mule Spinning Machine.

By way of a substitute for this actual inspection of the machine itself, we give here an illustration of the hand "mule" with a further detailed description. The "mule" (fig. 13) consists of two principal parts: a frame holding the drawing rollers, B, and a carriage, C, which runs forwards and backwards on iron rails and carries the spindles and the machinery connected with their working. The rovings *a, a*, as before remarked, pass through the stretcher B, and are attached to the ends of the spindles *b*. At the beginning the carriage is drawn in and the spindles are near to the stretching rollers. As the latter begin to revolve, the carriage is drawn away, so that after the rovings have been drawn out eight to ten times their original length, they are kept stretched and by the spindle revolving at the same time they receive a part of their twisting. When the carriage arrives at a distance of about 1·5 mètre from the stretcher, the rollers stop at once of their own accord, but the spindle still continues to revolve for a short time, in order to give the rovings the complete twisting required. This twisting is called first twisting and second twisting, and is done whilst the carriage is at a standstill, and not whilst it is in motion, in order to continue a slight stretching; and it is attained by making the carriage move faster than the front stretching rollers revolve. When this twisting is finished the spinner pushes the carriage to the stretcher at a suitable rate, and the length of yarn is taken up—*i.e.*, wound on the spindle. In order that the yarn, as it is wound on the spindle of the carriage, should form a spool rounded at the end, the spinner presses down with a wire, called the "faller" wire, a number of the threads. This wire is situated in the bend of the arm *c d*, and another wire prevents the threads being pressed down too much.

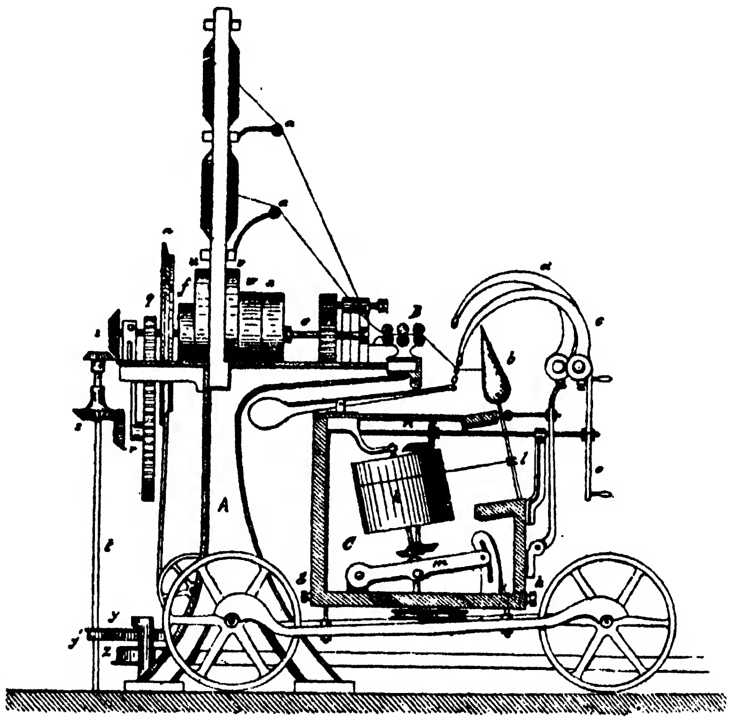


Fig. 13.

The moving and standing still of the drawing rollers is caused by the forward or backward moving of the shaft *e*, and the pushing forward of the carriage is caused by two wheels *i* and *q* situated on the same shaft. The wheel *i* revolves at the same rate as the axle, but *q* is made to revolve more slowly, by the bevelled wheels *s* and *r*. When the carriage has advanced two-thirds of its distance the shaft *t* is lowered by an arrangement, and *i* is disconnected and *s* comes into work. The wheel *y*, whose shaft carries the disc *z*, remains in connection with the wheel *y'*. In this way the stretcher is stopped, and for the last third of the distance that the carriage travels a stretching on that length of the thread and a continued twisting are produced. The turning of the spindle is caused by a

band passing round the drum *k* and the ring *l*. The movement of the drum and wheels in the carriage, during the moving of the carriage itself, is caused by the axle *m*, which receives its motion from the endless band *n*; for the twisting of the yarn the wheels *p* and the handle *o* serve. A mule of this description has 100, 200, or 300, and even more spindles. For 100 or 200 spindles they are made single, but for 300 they are made double: *i.e.*, the arrangement of wheels for conveying the motion is put in the middle, which lessens the manual labour, so that one spinner can look after two such machines.

Of the many improvements in the mule, the one made by Roberts of Manchester in the year 1825 is the most important. This invention was the "self-acting mule." Whereas in the ordinary or hand mule above described the retiring of the carriage and the winding of the yarn are caused by turning the handles on a flywheel by hand, this in Roberts' machine takes place through a special arrangement. This can be seen in fig. 14. The straps on *v x* are put on to the wheels *u* and *w*, and by means of *t* fastened to *u*, and the motion is carried by a wheel placed underneath and several toothed wheels to a drum. Round this drum a cord runs, and its ends are fastened to the hooks *g* and *h* at the front and back of the carriage. Whilst in the half self-actor the turning of the spindles and the pressing down of the winding wire have to be done by the spinner, the self-actor performs all these operations itself.

The advantages in using the self-actor are not few: saving in wages, better work than could be done by the best spinners, twisting more even than if done by hand, bobbins and cops firmer and all of one size and shape, and therefore taking up less room in packing, and when unwound or used as weft giving less broken threads and less waste. These great advantages have caused many patents to be brought out for different kinds of self-acting frames, and this ingenious machine is therefore universally used.

Reeling, sorting, and packing of yarn.—The yarn coming from the spinning frame is finished as yarn, but for its other uses it requires a little preparation. It is next reeled by a reeling machine, to turn it into skeins or hanks (numbers and counts) of known length. The yarn when divided into certain quantities and tied round the middle with a thread is known as a hank. The weight of a hank, ascertained by an ordinary balance and winding it on a delicately adjusted testing machine, determines the fineness of the yarn. The finer the yarn, the less weight in a hank, and therefore the more hanks in a pound. The fineness or count of the yarn is known from the number of hanks to a pound, and thereby we have a fixed system of numbers. The English is most often used. The hank has, therefore, 2520 feet, or 840 yards (761 mètres). A pound of No. 100 would contain 84,000 yards. The French reel has a circumference of $1\frac{3}{7}$ mètre, 70 times round the reel is a lea of 100 mètres, 10 leas are a hank of 1,000 mètres.

For prints, calicoes or knittings the counts from 30s to 60s are used, and for very fine batistes, mulls or muslin 150s to 250s are employed; yet in the London exhibition there was shown yarn as fine as No. 600s by a French spinner (Bautroyen and Mallet, in Lille), and No. 2150s by Houldsworth and Co., of Manchester; the former was shown as lace, muslin and sewing-cotton yarn, but the latter, of which there were 2150 hanks or 1,800,000 yards to a pound, was admired as a curiosity in spinning, though for practical services it was useless.

Yarn is sorted according to (1) the spinning frame used for its production; (2) the quality of the cotton and beauty or brilliancy of the yarn — firsts and seconds (best, good, middling, extra best, etc.); (3) the purpose to which it is going to be put—warp or weft; (4) the fineness, as shown above.

On account of the firmer twisting, water twist is used for nothing but warp, mule yarn is used for warp or weft; from which they are wrongly called, the former twist and the latter weft. Under the name medio twist, we understand hard twisted mule yarn. For weaving, mule yarn is used as slender "pear-shaped cylinders" called cops or pincops, which after having been taken off the spindles of the spinning jenny and put upon slender spools, are ready for using as weft in weaving.

Yarn for trade is made up in bundles fastened by string (the bundles varying in weight), and is packed by a screw-press or hydraulic press.

Processes through which Cotton Yarn goes preparatory to its being used for Weaving of Cloth.

At the end of last chapter we gave a general description of the methods of making up cotton yarn, both of warp and weft. Following on the spinning by the "throstle" and the "mule" are a certain number of operations to prepare the yarn for weaving. These we shall describe previous to taking up the important work of weaving just named.

The yarn known by the name of water-twist or throstle-twist, when not used on the premises for manufacturing, is sold in bundles. The bobbins which contain the yarn spun are taken to a very simple machine, called a "bobbin reel." The reason why it is so called is to distinguish it from another reel called a "cop reel." The only real difference between it and the bobbin reel is, that one makes the hanks from the cop and the other from the bobbin. In the bobbin reel the bobbins are put upon a spindle, but in the cop reel the cops are "skewered,"—*i.e.*, a thin wooden skewer is put through, and then the thick end of it is pressed into a hole in a rail,

which holds it in such a position that the yarn can be drawn from it freely. The bobbin reel takes the yarn off the bobbins as they are taking from the throstle. In both cases the yarn is folded round a fly, about 54 in. in circumference and about 12 ft. in length. The reel contains forty bobbins, which are all running at the same time on the fly, and in this way the hanks are made.

After the hanks are taken from the fly, they are generally made into a bundle of five or ten pounds weight. If the "count" of the yarn is called "forties" it is then made into a ten-pound bundle in the following manner. One "lea" contains 840 yards. Seven of those leas make one "hank," and forty of these hanks make one "pound." These forty hanks are put together, and then called a "knott," but more generally twenty of them are put together and are called "twenty-hank knotts." This division is done because forty hanks are too bulky to be made up neatly. Having twenty half-knotts instead of only ten full knotts, the head of the bundle shows twenty heads. They are put into an iron press, and are then pressed into a square-shaped bundle of very small compass. While in the press they are tied in about four places, so as to keep them in the same form when taken out of the press as they were while in it. When sent from the mill to the warehouse they are folded in brown paper and tied up with a thin twine called "casing twine."

The "cop reeling" process is precisely the same in all respects, cops being made at the mules instead of at the throstles. Cops are as often sold in the cop as in bundles; they are packed in skips containing 250 pounds each or thereabouts. When throstle or mule yarn is sold in bundles in this country, it is for the purpose of dyeing or bleaching. In no other condition can the yarn be delivered, so convenient for the purpose above alluded to, as that of being in bundles.

Methods of bleaching the yarn in the cop have been attempted by different processes, but as yet they have not been successful.

The cotton before being spun into yarn has also been bleached, but this system of bleaching seems to have died a natural death, as well as that of bleaching in the cop.

Throstle yarn is very commonly made into warps, and the warps are used in weaving, being employed for the longitudinal threads of the cloth, and termed "twist." The weft for manufacturing purposes is spun upon mules. The cops in that case are made very small—about the size of an ordinary man's finger —and they are known in the trade by the name of "pin cop" or "shuttle cop," being made so small as to be suitable in thickness and length for the shuttle of the weaving loom.

Before we enter upon the description of a "doubling frame," or the system of doubling two or more ends into one, whether for manufacturing purposes, for weaving into any kind of cloth or small wares, or for making sewing thread, we shall allude to a frame which is in use everywhere where coarse yarns are being doubled, and which is much used in finer yarns now—say up to 120s or 130s. For the finer yarns the practice of winding has only of late years been introduced to any extent worth mentioning. This winding frame, called a "cop winder," is certainly one of the simplest machines in a cotton mill. A long tin roller or cylinder runs from end to end of the frame. The frame contains a number of spindles, which stand upright, and are driven by bands which receive their motion from the cylinder above named. And this cylinder receives its motion from a belt which is driven from a shaft. The spindles have a "wharve," or small pulley, by which the band is kept in its position, and thus the spindle is always driven at a uniform speed. The cops as they come from the mule are "skewered," and the thick ends of the skewers are pushed into a rail which holds them steady while the yarn is being drawn off the cops. The spindles are furnished with bobbins. The bobbins, as they are driven round, of course draw the thread round them, the bobbins being so large that three, four or five cops can be wound upon them, and in this condition the yarn is taken to the doubling frame. Sometimes it is wound with a single end on to the bobbins, and in other instances two or more ends of thread are wound upon them.

The Doubling Frame for Yarn.

The process through which much of the single yarn has to pass is running two or more single ends together and then twisting them, which is called "doubling" or thread manufacturing. This system of doubling is worked only with mule yarn. Mule yarn having much less twist in it than throstle yarn, is all the better calculated for making double yarn: the threads being soft, it folds much closer than hard twisted yarn. The doubling frame very much resembles the throstle frame in all its working parts, excepting that of the rollers. In the doubling frame there are but two rollers, which are only intended to draw the yarn through at a uniform rate; so that every inch of such yarn will receive the same number of twists, and thus all parts of the doubled thread will be about the same strength. When two or more threads of single yarn are twisted together the strength of it is considerably increased. Doubled yarns, especially coarse ones, are used for a variety of manufactured goods.

THE TECHNICAL POINTS CONNECTED WITH THE EMPLOYMENT OF FORM AND COLOUR IN INDUSTRIAL DECORATION.

CHAPTER VI.

We concluded last chapter by describing—or attempting to describe, for no words can be found capable of describing that which is impossible to be explained—a fine study in colour and light-and-shade effects at a sea-margin. In trying to picture the beauties of the scene, we may here in continuation remark that what we then said did not complete those beauties. A light long strip of cloud passing athwart or across the sun threw a band of dark shadow right across the line of light—the sea of silver—somewhere about the middle of its length, from sand margin to heaven. Here, along and above this band, we had a cloud, now purple, now violet, now rose-coloured. But the interchanges, so to call them, of these colours were not abrupt, as the pupil not yet initiated into the study of colour might suppose, but gradually blended into each other in such a delicate way that it was difficult to say at what point the one colour or tint ended and the other began. This wonderful display of the loveliness of natural effects, which we are but too conscious of having failed miserably in an attempt to describe, did not, however, only afford many lessons of the most directly useful kind as regards colour and many of its characteristics; it yielded other lessons of quite as practical a character useful to the pupil in design. What those or some of the most suggestive of them were or are, we shall glance at presently.

Gradation in Colour.

The preceding paragraphs were taken up chiefly in pointing out the extreme value of the lessons which can be obtained in colour and its characteristics by close study in what has been called the school of nature,—the only school, in fact, in which true or right study of this subject vitally important to the design of industrial decoration can be studied. In attempting to describe a natural scene in which some beautifully suggestive and striking effects in colour were observable, we at the conclusion of the last paragraph pointed out to the pupil one characteristic—namely, the gradation of colour—in other words, the complete absence of all abruptness in the intermixture. We can get no other word than this to us unsatisfactory one of the many-coloured cloud which hovered over the shimmering waves of that lovely sea. Now, this gradation is a principle, so to call it, existing in natural objects, and is characteristic in them alike in form and colour. And if the pupil in art has as yet missed observing and noting it, he has still to learn a lesson of the highest value to him in his practice. To some, indeed, although pointed patiently out by their "master," the point never becomes clear, at least clear in all its subtilty; and this being so, is precisely the reason why such pupils in art never do become in the correct sense, or for the matter of that in any sense of the term, true artists—certainly not true colourists. Copyists they may be, and clever ones too, but "only this, and nothing more." We believe, however, that our readers have an ambition to belong to the higher of the two classes here named; and this being so, the youthful or beginners amongst them will, we feel assured, be but too anxious to obtain all the lessons which a knowledge of this principle of "gradation" or absence of abruptness in natural effects is so well calculated to afford. We have already made pointed reference to this as regards colour, but it is no less true of form — although, perhaps, more observable in the case of colour. And yet it may well be doubted whether it is observable to many: probably the most accurate way of putting the matter is to say that it is observable to the few only—those only who observe. For it is there to be seen if we only look to see it; but, as it has been already stated in more places than one in those papers in this work which treat more or less directly on art subjects, this capability to see must be cultivated. The eye, like the ear, has to be educated. And on this point of the gradation of colour it is difficult to over-estimate the value of the lessons in colour which Nature gives in such lavish and lovely profusion. This principle of gradation in colour is, however, one which to understand, must be studied in the book of nature itself; it is not one in which much can be definitely said here in ordinary book fashion. The very subtilty of the effects in nature which is one of the chief characteristics, if it be not the chief feature of this, precludes the possibility of giving a written or a *vivâ-voce* explanation of them. They must be seen in nature to be understood, and happy the artist who can so understand as to gain lessons from them. On this, the chief characteristic of gradation in natural colour, if we wish to give expression to it, we must go, as so many have gone before us, to find it in the words of the ablest, as he is the most graphic and graceful exponent of art subjects, John Ruskin. "What curvature," says this great writer in his "Modern Painters," "is to lines, gradation is to shade and colours. It is their infinity, and divides them into an infinite number of degrees. Absolutely without gradation no natural surface can possibly be, except under circumstances of so rare a conjunction as to amount to a *lusus naturæ*. . . . For instances of the complete absence of gradation we must look to man's work, or to his disease and decrepitude. Compare the gradated

colours of the rainbow with the stripes of a target, and the gradual deepening of the youthful bloom in the cheek, with an abrupt patch of rouge, or with the sharply drawn veins of old age. Gradation," he goes on to say, "gradation is so inseparable a quality of all natural shade, that the eye refuses, in painting, to understand a shadow which appears without it; while, on the other hand, nearly all the gradations of nature are so subtle, and between degrees of tint so slightly separated, that no human hand can in any wise equal, or do anything more than suggest the idea of them. In proportion to the space over which the gradation extends, and to its invisible subtlety, is its grandeur; and in proportion to its narrow limits and violent degrees, its vulgarity." How often this vulgarity is displayed in such attempts at colour as many of our art-decorators make in trying to add the beauty of colour to our surroundings, let the experience of the past generation or two, and, indeed, we may say, of the present one, tell us. True, our art-decorators do not, many of them, treat us much or often with the effects of colour; for it is one of the unhappy characteristics of the times we live in, that we have lost, in very large measure, that love of colour, and that sense of the healthy mental and, we might say, moral influences which colour widely and wisely used can impart, and which our ancestors, specially those of the middle ages, possessed in so great a degree. The great authority we have already quoted speaks truly when he speaks of the sacredness of colour, and that it is of necessity connected with all purity of mind and nobleness of feeling. He tells us to "consider for a little while what sort of a world it would be if all flowers were grey, all leaves black, and the sky *brown*. . . Then observe how constantly innocent things are bright in colour: look at a dove's neck, and compare it with the grey back of the viper." Taking a wide view of the subject—for, as our authority says, if there were no exceptions to this rule, "it would be more convincing than the lessons of the natural universe are intended to be"—taking a wider view, let us "compare generally rainbows, sunrises, roses, violets, butterflies, birds, gold-fish, rubies, opals, and corals, with alligators, hippopotami, lions, wolves, bears, swine, sharks, slugs, bones, fungi, fogs, and corrupting, stinging, destroying things in general;" and we shall find then "how the question stands between the colourists and chiaroscurists, which of them have nature and life on their side, and which have sin and death." And we may here note that a well-known—but too well-known and but too much admired by a certain class, unfortunately—school of art gives a very striking illustration of the truth shadowed forth in the last sentence of our great authority. For this school of painters, happily not indigenous to this country, but flourishing chiefly, if not wholly, on the Continent, which, admittedly and for the most part shamelessly, so far as some of its members are concerned, dealing with subjects which minister to the depraved tendencies of our nature, produce subjects noticeably deficient in the effects of pure colour, and where colour is employed at all it is of those browns and greys which are generally the exponents of hurtful things, of death-like, deadly influences. "All men," to return to our great authority, "all men completely organised and justly tempered enjoy colour; it is meant for the perpetual comfort and delight of the human heart; it is richly bestowed on the highest works of creation, and the eminent sign and seal of perfection in them; being associated with *life* in the human body, with *light* in the sky, with *purity* and hardness in the earth; death, night, and pollution of all kinds being colourless."

Gradation of Form.

So marked a feature is this gradation of tone and tint of all natural objects, that, comparatively seldom as absolutely flat surfaces are found in nature, the majority of objects having surfaces of curvature more or less decided, even such surfaces, as so clearly pointed out by Mr. Ruskin, are furnished, so to say, with this effect of gradation, the means being "provided in local colour, aerial perspective, reflected lights, etc., from which it is but barely conceivable that they should ever escape." Natural effects can best, can indeed only be seen, and the lessons they teach only be learned, by going to Nature herself—a truth not quite so obvious to many, absolute truth though it be, to judge from the fact that they rarely go to Nature at all, preferring to study in such fashion as they can from models and copies; and not always from these, at least not from admittedly good ones, preferring as they do sometimes to follow the lead of what they call or conceive to be their "own genius," which, "will-o'-the-wisp" like, but too frequently leads them into the morass and the quagmire of weakness, inefficiency, and often to absolute artistic death. We feel assured that none even of our most youthful and inexperienced artist readers will ever be led away by any such specious, yet, it must be confessed, to human nature but too attractive notion of their own ability, to dispense with the unobtrusive but always great and striking lessons which Nature is ever so ready to give to her patient, willing, and receptive students.

To Nature herself the student must go to learn those lessons which have the only claim to be considered as artistic. Class "copies" and school "casts" are of great service to the artistic pupil, and cannot, any more than the lessons of the teachers, be dispensed with; but they are only useful in their place.

THE STEEL MAKER.

The Details of His Work—The Principles of its Processes—The Qualities and Characteristics of its Products.

CHAPTER XIV.

In continuation of the subject of qualities of steel, commenced in last paragraph of the preceding chapter, we have to say that another steel, with the requisite qualities for ship building, of which a capability to resist blows or shocks which would crack, split up or open up ordinary iron, but which, however much bulged or "dinged" in, would still be free from cracks, is obtained by adding from 0·15 to 0·20 per cent. of carbon. Again, for a mild steel required for bridge and roof work, one possessing a greater resisting strength against pressures tending to break the metal across, the percentage of carbon is from 0·3 to 0·35. And in the case of a steel required for railway "metal," or the "rails," where hardness is required, and a capability to resist abrading or rubbing down and exfoliating action, the latter having a tendency to make the metal split up into plates or leaves—so marked a characteristic of wrought-iron railway bars —the percentage of carbon is from 0·4 to 0·5. We thus see how wide the range is of steels required for different constructive purposes; but frequently the percentages of carbon present in or given to them change (from 0·5 up to 1·25 per cent.), and yet how very minute are the percentages actually used, and the differences between them as employed in different cases giving different characteristics!

Debasing Elements in the Iron.—A Difficulty in the Bessemer Process.—Sulphur and Phosphorus.

But the art of the mild-steel maker would be one comparatively easy to carry out, if it were merely a matter of giving a certain proportion of carbon to one sample and another proportion to another sample. But this is not so: it is a vastly more complicated problem which the steel maker has to solve in his daily practice. This arises from the conflicting, and what, in view of the facts as they exist, we may well call the contradictory elements, present in the materials with which he has to deal. If the reader has been careful to note the various points brought forward for his consideration within the range of the various chapters of the present series, as well as those of the series entitled "The Iron Maker" (which it is of course presumed he has studied previously or at least in conjunction with the present series), he will remember the very great differences existing in the ores and materials used in the manufacture of iron, which is the basis of all the mild steels produced by the Bessemer process, or by the Siemens process. These differences arise from the varying constituents of the ores and materials employed; and if those constituting the majority are what are called "debasing"—that is, having a tendency to deteriorate —in proportion to their presence the constructive value of the metals made from them is reduced. Some of these debasing constituents we have seen that those of phosphorus and sulphur, while most dreaded by the steel maker, are unfortunately—especially the phosphorus—the most frequently and largely met with in the ores of iron, from which his steels are made. We have seen in a recent paragraph how Sir Henry Bessemer had the success of his invention or discovery greatly imperilled by the presence but too abundantly of phosphorus in the ores with which he first carried out his process. This element of phosphorus being present in comparatively low percentage in Swedish iron—which has long held the reputation of being the purest in the market— the "converter" process was successful in producing good steel free from the defect known as "cold short," which lessens the forging and working value of a metal very materially. But this fine quality of iron is not only dear, but is comparatively scarce—the dearness being caused by its scarcity—so that if the Bessemer or converter process had depended upon the supply of this Swedish iron, it would never have attained anything like the gigantic proportions which we all know it has reached, as a trade and a commercial power, in our country. We have seen how the red hæmatite ores, of which the Ulverstone district is the principal source, came to the rescue of the converter process and saved it from the probable fate of a comparatively limited range of action.

Of these two debasing elements in iron ores, while that of phosphorus is the worst with which the steel maker has to deal, that of sulphur brings about evils of its own which are bad enough in their way. Of these evils one is the property which sulphur gives to the metal known as "red short" (see the papers "The Iron Maker"), a quality which, if existing to large extent, renders the metal incapable practically of being worked or forged. But this debasing element of sulphur brings about another evil in the steel, which at one time threatened the success of the Bessemer or converter process. This remains to be described, as also how it was at last successfully overcome. Our readers, especially if practically acquainted with workshop practice, will easily understand how the value of a metal, such as a bar of steel, will depend greatly upon its being of uniform quality throughout its whole body. This uniformity is not merely of a chemical character; in fact, analysis might show that any two portions taken from two different and distinct parts of the same bar were of precisely the same quality. But while chemically homogeneous or equal in character, it might not be so practically. In breaking up a "pig" or bar of cast iron, it will

sometimes be found that in the very centre of it vacant spaces—frequently very large in proportion to the cross section at the broken parts—will be met with. These spaces are popularly, and to a certain extent correctly, called air-holes, and in the same way the metal is said to be air-blown. When the air-holes or vacuities are more or less numerous throughout the block it is said to be "honeycombed," this term being perhaps more frequently applied to the blocks or ingots of mild steel cast on the Bessemer or converter process. For it was this evil of honeycombing which was met with in its early stages, and which then threatened its success. These cells or honeycomb spaces were caused by the presence of gases, generally oxygen, sometimes carbonic-oxide gas, these gases being shut up, inclosed, or "occluded," as the technical phrase has it, within the interior of the block or ingot of steel produced by the converter. We have already alluded to spiegeleisen. This ore is rich in manganese, a constituent of ores which Heathcoat, who was one of the most successful of steel makers under the ordinary system, a description of which we have given, showed was most useful in the making of steel. Mushet, another worker in the field of metallurgy, to whom the science is, beyond a doubt, greatly indebted, had his attention drawn to the value of spiegeleisen as containing a high percentage of manganese; and he took out a patent for its application to the process of steel making on the converter or blowing process, believing that by its use the manganese present in the ore would so act upon the oxygen—being itself readily oxidised, combining this with the oxygen present in the steel—that its occlusion or shutting up within the body of the ingot or block would thus prevent the formation of the gas cells, which we have seen to be the cause of the ingot or block being honeycombed. This was found to be precisely the result of using spiegeleisen—added at or near the end of the blow—to the metal in the converter. We may here note, parenthetically, that the evil of honeycombed steel is got rid of, as well as great advantages specially due to the operation obtained, by the process of compressing steel ingots under enormous artificial pressure, patented by Sir Joseph Whitworth, the well-known and able mechanician, whose recent death has been a great loss to practical science. By one of those unfortunate circumstances which happen now and then to most business men, Mushet did not profit by his discovery of the value of spiegeleisen in the converter process of steel making, his agent, it is said, having neglected to pay the fees due at the Patent Office in time to secure the patent.

Manganese in the Bessemer Process.

The valuable, or as we should rather say the invaluable properties of manganese, the active agent in the spiegeleisen, in getting rid of the honeycomb or porous condition, as it may well be called, having thus been established, it is scarcely necessary to say, after giving in the present series of papers, and that under the title of "The Iron Maker," so many proofs of the energetic activity and the inventive ability of those connected with the manufacture of iron and steel, that the attention of both practical metallurgists and metallurgical chemists was drawn to discover methods of increasing the value of manganese as a constituent in mild steel making, and making its use more and more available over a wider range of practice. Spiegeleisen, although itself so valuable as a source of manganese, contained but a comparatively small percentage of this constituent—some 9 or 10 per cent. only. By various means a "spiegel" was produced in which this percentage of manganese was increased threefold. But it was not until a new alloy of iron was discovered, capable of being produced in any desired quantity, that the steel maker had a product in which the manganese was increased to an extent not far off if not quite eightfold of that present in ordinary spiegeleisen. This new alloy received the name of "ferro-manganese," which admirably indicated its peculiarities. This gave the steel maker a power of producing a variety of steels of almost the widest possible character—at least so wide in its range that practically almost any quality of steel required by the constructor might be produced. Before this new alloy was introduced the difficulty in attempting to increase the quantity of manganese given to the metal in the converter was to keep down the increase of the carbon to too high proportion, for this when so present gave the steel too high a degree of hardness. But by the use of the new alloy, while it was possible to increase the percentage of manganese, this could be done so that the carbon was not increased to the dangerous point, while at the same time the steel maker had the power to lower the percentage of carbon without losing the manganese, the value of which in preventing the honeycombing of the steel, or preventing it from becoming what may be called spongy, we have already seen. The ferro-manganese now so largely used contains also a proportion of silicon. This, from what we have stated in the series of papers under the heading of "The Iron Maker," is a debasing ingredient in it, as tending to reduce the metallic value of the iron ore. This ingredient is present to a percentage as high in some instances as one-twentieth, even in the red hæmatite ores, which we have seen are so valuable for the converter process of steel making that the pig iron made from them is classed in the trade as "Bessemer pigs." Notwithstanding, however, that silicon is a debasing ingredient in iron ores, it is but right to state that it is not objected to by some makers, inasmuch as its presence

so aids the process of active combustion going on within the converter during the "blow" by the great heat developed. Notwithstanding this, in pig iron used by steel makers, it is part of the understanding that they are to be supplied with qualities in which the silicon shall be as low as is consistent with the due working of the metal, the percentage of phosphorus being at 0·05, that of the sulphur 0·06. We shall see in a succeeding chapter how these two latter most mischievous agents in steel making are now got rid of, and in a way so generally applicable that even the poorest ores used in the trade to a large extent are capable of making mild steels of a high quality.

Points connected with the Actual Working of the Bessemer Process.

Having in the two last chapters gone fully into the several points connected with the Bessemer or converter process of steel making, we are now in a position to follow up the details of its actual working, some of which we have already stated. In the last chapter we pointed out that as worked in the earlier stages of its history it was a much more complicated process than it is now. At first the pig iron to be made into steel in the converter was heated in a "reverberatory furnace," the operation of which was supposed to be necessary to the complete working of the system. We have seen how this was done away with and the pig iron melted in the ordinary iron founder's cupola, or in one or other of its improved forms, such as that known as Ireland's. We have seen also that a further step in the simplification of the process was taken by doing away with the cupola furnace, and this by taking the pig or cast iron direct from the blast furnace (see "The Iron Maker" for a description of the cast-iron manufacture) to the converter. The metal as it flows from the blast furnace is led to an iron vessel or ladle of large dimensions, holding many tons of metal; this is lined, of course, with a refractory material known as "ganister," and is placed upon and forms part for the time being of a small bogey or carriage. This is, along with other carriages containing the melted pig iron, conveyed by a small locomotive along the rails leading from the vicinity of the blast furnace to that part of the works where the converting process is carried on. The number of these vessels or trucks seen here and there over the place in a large establishment is one of its most striking features to the visitor to whom iron and steel making are novelties. And if he is observant he may discover, somewhat to his surprise, how long the period is during which the pig iron taken from the blast furnace remains liquid after being placed in the vessel or ladle of the small carriage or bogey. This is due partly, indeed chiefly, to the non-conducting material with which the vessel is lined, and to a species of skin which covers the surface. On looking at those vessels so filled with molten cast iron, and which may be standing in long rows ready to be wheeled off by the small locomotive to the converter, the visitor at first has no conception that they are filled with a material so certain to be dangerous if one of the vessels happened to be overturned in transit, or collided with another train of similarly filled vessels. If inadvertently standing near them, the visitor may be conscious of a considerable degree of heat; but if not specially informed or otherwise aware of this fact, he will have but little conception as to what their contents may be, so innocent-looking of all containing red-hot metal do they generally appear. On arriving at the converting place the vessels are hoisted up and poured into the mouth of the converter, and the blow is commenced and carried out in the way we have in a preceding chapter described.

The first time a visitor to one of our large iron and steel works witnesses the "blow," as it is technically termed, of a Bessemer converter, will be a marked epoch in his practical life. Without in any way being desirous to perpetrate a pun, we may say that it will truly be a "red letter day" with him in the future. For assuredly, apart altogether from such mental or intellectual considerations as with a thoughtful man will be sure to arise in witnessing such an example of the power of man over material obstacles, the "blow" is a grand and striking spectacle, more especially if witnessed at dusk, or better still when dark, if indeed darkness really exists within the precincts of one of our large iron works, where, as in the Middlesbrough district, many blast furnaces are and more than one converter may be at work. Grand and striking as are the effects of one of the fine displays of fireworks for which the Crystal Palace at Sydenham is famous, the spectator for the first time of a "Bessemer blow" will acknowledge that the fireworks must before the grand effects of this "pale their ineffectual fires." The writer of these lines has stood during successive "blows" in company with men who, although they have witnessed blows without number, have been beyond doubt impressed with the sight—not, of course, as much as if it were novel to them, but still in so marked a manner as to show how it maintained its power over their imagination and intellect as well. Nor, while witnessing the marvellous effects of the blow taken throughout from beginning to end, when the converter is "turned" or emptied of its glowing contents, will the spectator to whom the sight is novel, if he be at least of an observant turn of mind, fail to be struck with another and a most striking feature of the process. This is the astounding ease with which all its details are carried out.

THE IRON MAKER.

THE DETAILS OF HIS WORK AND THE PRINCIPLES OF ITS PROCESSES.

CHAPTER XV.

THE regenerative stoves described at end of preceding chapter are readily cleaned with a brush; at the top is a large movable cap, *d d*, fig. 6, Plate CLVI., for the purpose of getting readily at all the openings.

For the purpose of removing from the gas any dust it may hold in suspension, the stove is provided with a simple contrivance for washing the gas. This gas washer not only removes all dust, but also an infusible ash that collects in it, and also catches the ore dust which forms a fusible iron silicate which glazes the walls. Above the gas washer is a dust collector. This latter provision is made for the purpose of relieving the washer of part of its work.

"To burn gas thoroughly," says Mr. John M. Hartman, of Philadelphia, "combustion must take place in a large chamber, with thick walls maintained at a high heat. In these stoves the gas is cut up into strips, by passing it through slots in the bottom of the stoves, as shown in plan at *b*, fig. 1, Plate CLXXXIII., then mixed with air, and by the time it has travelled forty-five feet to the top, *b*, fig. 6, Plate CLVI., of the regenerator, it is thoroughly burned. The regenerator is supported on cast-iron gratings, with a space below for draught passage to the chimney and blast passage when the stove is on blast. Ample provision is made in the walls for expansion, and by using an air-space between the shell and wall the heat lost through the shell is reduced to a minimum."

In order to relieve the pressure which exists in the interior of the stove whenever the gas is put on, there is a piston blow-off valve placed near the nozzle of the chimney. The blast itself works this valve. There is also a cold blast valve, which can readily be opened or shut; it is simply a pivot valve. "The use of the gas washer and the piston blow-off valve," we are told, "and the practice of blowing through the stoves twice a week, prevents accumulation of dust, and insures regular working." "The patents on these stoves," continues Mr. Hartman, "give them the exclusive right of cleaning by this method." The valves themselves are plain valves. The chimney valve is kept sufficiently cool by means of a circulation of air which is drawn through it by the chimney. The hot-blast valve and the gas valve are kept cool by means of water. The valves are situated on one side of the centre, so that they are made to lie against the surface and remove any deposit that may be on it. In order to provide against the stem binding, the gland has a side motion. The valve and cap, also, can be taken off in a few minutes by simply "slacking up the four belts holding the cap and winding up the chain" For each stove a stream of water not more than half an inch is all that is required, while the valves can be run without any when the blast is not more than 120°.

The mode of operation of these stoves is thus described by the same writer named above. The stoves "are opened and gas burned in them four hours, when they are closed and the blast blown through them for two hours. Three hours are required to give the stoves time to heat up. The flues connecting these stoves are all overhead, and can be cleaned at casting time in ten minutes. Owing to the small amount of gas used, the flues are small. This is due to pure gas and large heating surface. On first turning a stove on a blow, the temperature of the blast is higher than required, and as the blow continues this temperature falls, and by the end of the blow it is too low. To obviate this, and obtain a uniform temperature, a connection is made from the cold-blast to the hot-blast pipe. In this pipe is placed a valve with a clock attachment, to gradually close the valve during two hours. At the beginning of the blow this valve is wide open, and admits a certain volume of cold air, which cools down the hot blast to the proper temperature. This cold air does not rob the stove of heat, but simply equalises the temperature of the blast during the time the stove is in work supplying hot air for the blast. The amount of air heated per minute (in a blow of two hours) to a given temperature, and the temperature of the escaping gas, are the measures of efficiency of fire-brick stoves." These stoves, constructed as they are of brickwork, are well calculated to resist injury on account of damp, since any water contained in the air entering the furnace is decomposed into hydrogen and oxygen. In fig. 6, Plate CLVI., *f f* is the valve and flue leading the gas from the "down-comer" to the combustion chamber *b b*, being split up as it passes into the chamber by the three apertures at bottom, as shown in plan in fig. 1, Plate CLXXXIII. In fig. 6, Plate CLVI., *g* shows the air flue to admit air to flash the gas into flame in the combustion chamber *b b*. The arrows show the course of the gas in this chamber leading to the regenerative chamber *c c*, from which it passes off as shown by arrows at right-hand flue at base, with its heat os imparted to the brick regenerative surfaces in *c c* that its temperature is so low as 250°, thus showing how little heat is lost.

Tuyères of the Blast Furnace, or Nozzle through which the Hot Air is passed into the Furnace.

Before proceeding to other departments of the subject, in connection with the blast furnace arrangements, a notice here of the water tuyère is necessary. From what has been said on the subject of the

process of combustion going on in the furnace, the reader will have some idea of the intense heat generated within it, and specially at points near the lower part, or the region in which the process of reduction of the ore is being completed; and at a special point of which the tube or pipe conveying the blast of air enters the furnace. With so high a temperature reigning at this point, the material, universally iron, of which the blowpipe, so to call it, is made, would be almost instantly destroyed. To prevent the nozzle or orifice part of the blast-pipe from being thus instantly destroyed, the contrivance known as the "water tuyère" or "tweer," as it is called in the vernacular of iron workers — which by the way is almost a phonetic way of giving the correct French pronunciation of the word tuyère, which means a pipe or tube—has been introduced. The principle upon which this contrivance is based is a well known and simple one: that the temperature of water boiled in an open vessel—that is, in which the products, as vapour or steam, have free connection with the atmosphere—never rise above a certain temperature, however long the process of heating or boiling continues, the supply of water to the vessel being constant, to make up for the portion evaporated or passed off as vapour or steam. Fig. 2, Plate CLXXXIV., illustrates in simple diagram one method by which this principle is carried out, to prevent the nozzle of the blast-pipe becoming destroyed by the intense heat reigning within the furnace. In this *a a* represents a double-cased vessel of iron; into the space, as *b b*, shown in section to the right of the diagram, formed between the inner and outer shells or casings, water is kept continually supplied, passing in by the supply pipe *c* and out by the delivery pipe *d*. There is thus kept up within the casing a continually changing current of water. This casing, or double shell, is passed into a space provided in the furnace at its lower part, at the point where the blast of air is to enter it, and so made tight that in the event of an accident happening, or repair being required, it can be taken out with comparative ease. However intense may be the temperature within the furnace at the point where the casing *a a* is passed in, the water, although rapidly heated, is maintained at such a low temperature, and this also is the condition of the air within the casing, as at the part *e* in section. And it is at this point that the nozzle, *f*, of the blast-pipe terminates. In the improved forms of water tuyère, in place of having the vessel, as *a a*, double-cased, it is made up of a coil of pipe or a spiral tube; the convolutions of which are represented by the dotted circular lines in the elevation in fig. 2, Plate CLXXXIV. Several forms of water tuyères have been introduced—as, for example, that which is known as the water spray tuyère. In this the water, in place of being contained in a solid form in a shell or a spiral tube, as above described, is projected into the interior of the casing, as *a a*, fig. 14, into which the nozzle of the blast pipe is passed in a series of small jets. These project against the whole interior surface of the iron shell, or casing, and keep it at low temperature, and so also the space into which the nozzle of the blast pipe is passed.

The Making of Wrought or Malleable Iron.—Introductory Remarks.

We have in preceding chapters gone into all the points connected with the ores of iron, and those involved in the reduction or smelting into the form of metallic iron, or, as it is in general terms known simply as iron. These points include a great variety of information necessary to be known by the student of practical metallurgy, which will enable him, if he thoroughly understands them, to follow up intelligently the further progress of the iron manufacture, as well as the points connected with the making of steel, the details of which will occupy his attention in the special papers devoted to it. We are now prepared to follow up the processes of making that form of the irons of commerce known as wrought iron or malleable iron.

In the modern methods of iron making, the basis of wrought or malleable iron is pig or cast iron, the production of which has hitherto occupied our attention. In the ancient methods of iron making we have seen that from the same process iron in its two forms of wrought and of steel might be produced. And we have seen also that in many cases it would be doubtful whether the iron worker of those early times knew positively when he had obtained steel from his furnace, and when he had obtained a product which we now designate malleable or wrought iron. This uncertainty as to his products was brought about by the peculiar method of working which in early times was alone open to him. In the furnace he employed it was not possible to obtain such an intense heat as to be able to produce a metal the fluid of which could be run out, and which in proportion to its contained carbon would be either wrought iron as we know it, or mild or Bessemer steel, a steel known by this name, and having peculiarities described in the papers "The Steel Maker," and used for edge or cutting tools. The comparatively low heat obtained in the early forms of furnaces gave the metallic product, as we have seen, in the form of a spongy mass, which on being taken out of the furnace was subjected to hammering, by which the cinder was expelled, and malleable iron, as a rule, was the product. In making wrought iron—or, as from the circumstance of its being able to be formed or beaten into any desired shape, while heated to a red-hot temperature, by hammering it is sometimes called, malleable iron—in

the early times of the iron manufacture, the workman took a portion of the spongy mass of reduced ore named above, and gathered it by means of an iron rod into the rough form of a ball or round mass. To this the technical name of "bloom" was given. Hence the name by which iron works were long and in some districts are still known, as "bloomeries." On being thus gathered up into a mass sufficiently large, but not too large, for the convenience of easy handling, it was taken out of the furnace and carried to the anvil and there subjected to a vigorous and comparatively long "hammering." The skill of the workman, so far as the furnace work was concerned, in preparing the "bloom"—that is, getting up a portion of the pasty, spongy mass present in the furnace—lay in so manipulating the ball or bloom, while subjected to the intense heat of the furnace, that this should so act upon it that it came most rapidly to that precise condition in which, if taken out and submitted to the hammering process, it would take so "kindly to this," to use a common expression, that the hammering would be done in the way most effectual in reducing the bloom to the required condition. In this condition the impurities, or the most part of them, would be forced or squeezed out, leaving the mass of iron as pure as possible and free from all slag or "cinder," as the impurities were technically called. This obtainment of as pure a quality of wrought iron—which in the early times of iron working, when the finest ores were almost alone used, was often, as we have already remarked, just as likely as not to be of the quality of metal which we now call mild or soft steel — depended very much on the condition in which the "bloom" or ball of pasty-like iron was taken out of the furnace. If this was not attended to by the workman, who from comparatively early times in the history of the trade was termed a "puddler," or "paddler," from the peculiar character of his work, the iron when placed under the hammer would, by hissing and spurting, or by a "behaviour" which would soon become familiar to the workman, show that it was not taking kindly to the process, and would not yield a quality of iron of the purity or freedom from cinder desired. In such cases the bloom had to be returned to the furnace to be reheated, brought to the pasty condition, and formed by the workman into the required form of bloom before it was again passed under the hammer. This failure of the puddler to bring the bloom to the anvil in the condition best fitted to give the required quality to it after being hammered was of course equivalent to a loss of time. But it involved more than this: a loss of metal was sure to be the result; and this, however small in proportion to the weight of the whole bloom in a single instance, becomes a serious matter if a number of blooms were so badly or carelessly treated in the furnace. A further evil was likely to arise from first carelessness in attention to the puddling process —namely, the loss which might and often did arise from the burning or overheating of portions of the bloom. All those drawbacks, added to the evident loss of time arising from the circumstance, made the giving of a bad bloom by the puddler or furnaceman to be looked upon as a serious offence on his part, which from pretty early times in the trade was punished with more or less severity. When the bloom was in the condition best fitted under the hammering process to give the desired good quality of wrought iron, the metal in the technical phrase was said to be "brought to nature"—a curious phrase, which however indicates clearly enough what is meant by it. If not in proper condition, the "bloom" was rejected by the workman and thrown back into the furnace, and was itself designated by a term quite as or even more singular—namely, a "shadrach," the derivation of which is obvious to those acquainted with the leading facts of Scripture history. The furnaceman or puddler, therefore, to whom many of those "shadrachs" were assigned in the course of his daily labour, would not stand high as an efficient workman. The points involved in the foregoing considerations have a most intimately practical bearing upon the manufacture of wrought iron as carried on in the modern processes of the trade. They indicate that in preparing the bloom or the mass of iron which has to be hammered in order to force out as much of its impurities as can be expelled by the process, personal attention must be given by the workman to what he is about. It is essential that he should closely observe, or to use the popular phrase, see what he is doing, so that he does it well. In other words, "mind" must be given to the work; for without intelligence, while it may be well done, the chances are that it will be ill done, and nothing in good work is left to chance where by giving mind a certainty may be secured more or less efficiently. It is this circumstance which throws such difficulties around the proposals to substitute machinery for the manual labour of so preparing the mass of iron in the furnace that it will be taken out only when "brought to nature." For a machine cannot think, can exercise no powers of selection where observation and thought are required. And those difficulties in the work of the modern trade, where a certain complication of processes is met with, are difficult to deal with as compared with the simple method of taking the mass of pasty iron from the same furnace in which the ore was reduced.

The Wrought Iron Manufacture.—The Refining Furnace.

In the modern method of manufacturing wrought or malleable iron the conditions are altogether changed;

and it is those which give rise to the complications above alluded to, which make the application of machinery to the work of the puddler such a difficult problem to solve. This will be more clearly seen when we understand what the process of modern wrought iron making is. To help the reader to this comprehension of it we now proceed to present him with sundry remarks. We have said that wrought iron is now produced from cast or "pig iron," a product which was unknown practically, at least so to the early iron workers; and we have seen to how large an extent pig iron is adulterated — to use an easily understood term—by various debasing constituents or ingredients chiefly present naturally in the ore itself, but also derivable partly from the materials of the charge delivered to the blast furnace. The principal debasing ingredients or constituents of cast iron are sulphur and phosphorus; and as we have seen in this paper, and as is further explained in the series entitled "The Steel Maker," nearly all the attempts made in recent and comparatively recent times to improve the manufacture of iron have had as their main object in view the removal of these two constituents so frequently and in some cases so largely present in iron ores.

Cast, or as it is better known in "the trade," pig iron, is chiefly distinguished from other forms of iron by its excess of carbon. Roughly or generally defined, therefore, the art of making wrought or malleable iron consists in getting rid of this excess of carbon. A process of oxidation or oxidising has to be gone through, and the readiest way to effect this is to place the pig iron, in a melted or fused condition, in contact with large volumes of air, which, as is well known, contains a large percentage of oxygen. That this process was the first which was introduced into practice in the making of wrought from pig or cast iron, there is every reason to believe. The first form which the process assumed was one in which the principal feature of the cast iron manufacture itself was reproduced —namely, the "blast" of atmospheric air. The cast or pig iron to be converted into wrought iron was melted in a special furnace by immediate or direct contact with the fuel, and in its melted condition subjected to the oxidising effect of the blast of air. As the object in view was practically the getting rid of the debasing constituents present in the iron, as well as in decarbonising it—in other words, refining the cast iron—the process was termed that of the "refinery," or still more briefly the "finery," and the furnace employed "the refinery or refining furnace." Well aware of the influence of the fuel employed in the ordinary process of pig iron making, in often through its impurities adding to its debasing constituents the early users of the finery or "refinery" took care to reduce to a minimum all chances of this kind by using as a fuel, not coal or coke, but charcoal. This expensive fuel was however in this country used only to a limited extent, and for reasons which will be obvious to the reader if he draws to recollection what we have given in the early chapters of this present series of papers. Its use, however, was the rule in the chief seat of the iron works in the north of Europe—Sweden, and it is there still employed in the manufacture of that form of wrought iron known to the trade as "Swedish" or "charcoal iron," and which, the best in the market, is generally taken as the standard wrought iron, constituting as it does the nearest approach to what the best malleable or wrought iron is. Various forms of furnaces were introduced, but the best form of the "refinery" furnace, and that which is still used in Sweden, is that known as the "Lancashire hearth." We give in fig. 4, Plate CLXXXIV., a diagram which, while it explains in a general way the refining part of the furnace, explains also the principle upon which this process of making wrought out of pig iron is based. Part of the furnace is shown at *a a*, *b* is the "hearth" or furnace bed or bottom, on which the charcoal fuel *c* is placed, and by the combination of which the pig iron or cast iron is fused or reduced to a molten condition. The combustion of the charcoal is intensified, and oxidation also of the molten iron is caused, by the blast of air forced into the furnace interior, *e*, through the tuyères at *h* and the nozzle *g* of the blast-pipe *f*. The air may be heated—thus giving a hot blast—by the waste heat of the furnace *a a b c* being passed in contact with heating pipes placed in a chamber *e* shown in dotted lines at *h*, this being immediately above the furnace *c*. The process of decarbonising or oxidation, and the getting rid of the impurities such as phosphorus and sulphur, the latter passing out in the resulting cinder or slag, was early found to be greatly aided by stirring or raising and breaking up the mass of molten pig iron lying on the hearth *b* by means of the iron rod, technically known in the iron making districts as a "rabble," sometimes called a "fettling bar" (the term "fettle" a Lancashire word in general use amongst the working classes, meaning generally to set a thing right, to repair or do a certain piece of work). The pig iron in its raw or usual condition, containing so much carbon, and being thus the more easily melted, has, as it becomes molten, a tendency to run to the bottom part of the hearth, and thus become more or less solidified. The object of the stirring up of the contents of the hearth or furnace *b c* by means of the rabble or iron rod is to bring it, by breaking up this molten mass, more and more within the sphere of action of the blast in the immediate neighbourhood of the tuyères, *h*.

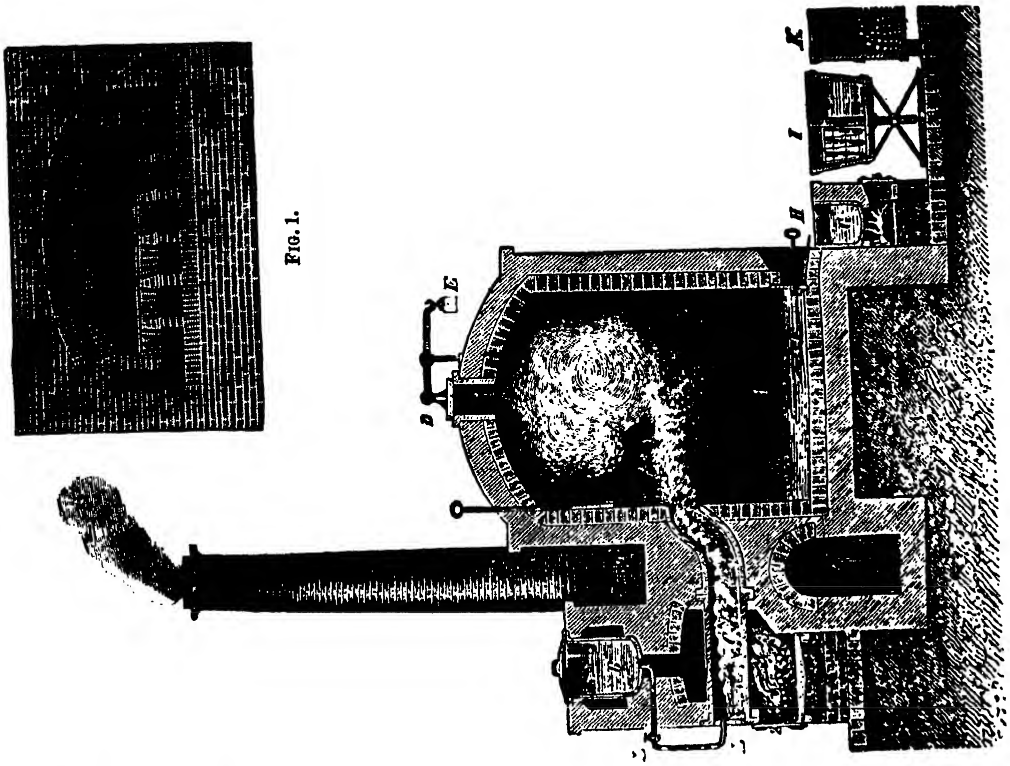


FIG. 1.

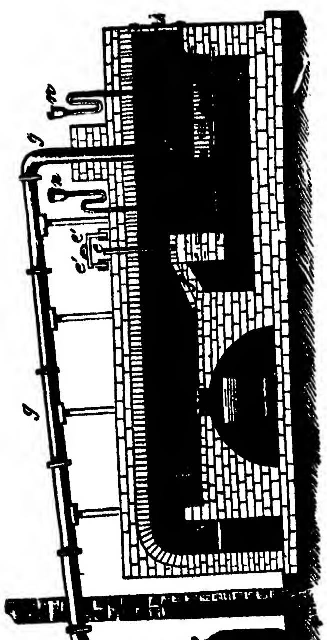
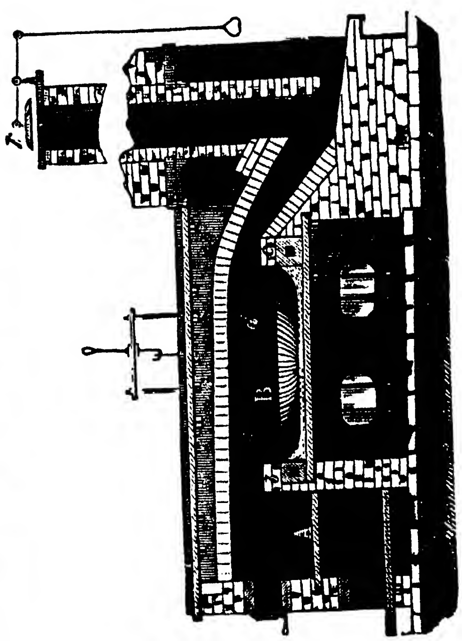


FIG. 3.



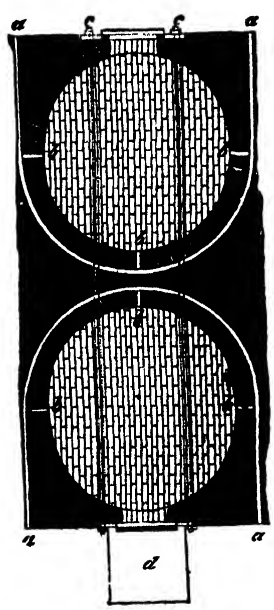


FIG. 5.

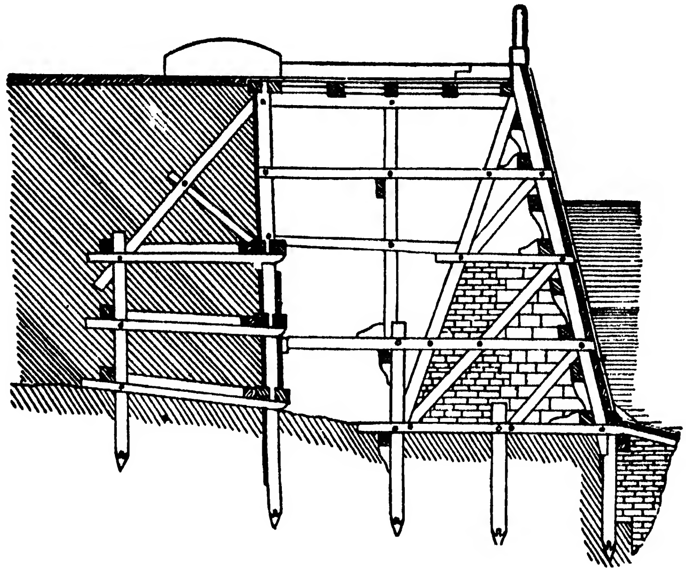


FIG. 1

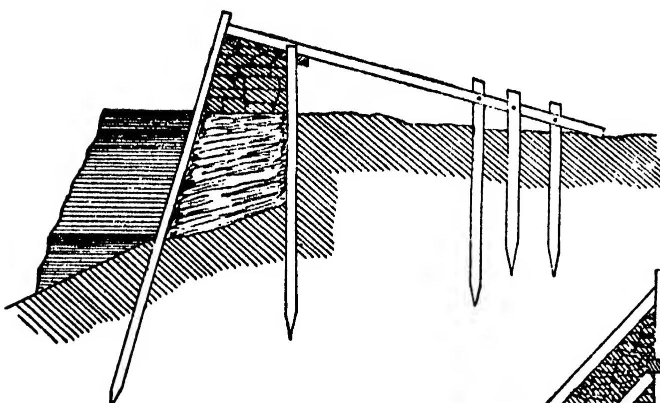


FIG. 2.

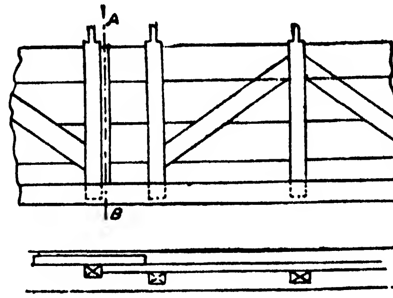


FIG. 3.

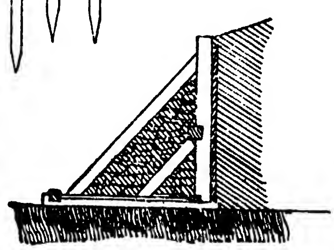


FIG. 4.

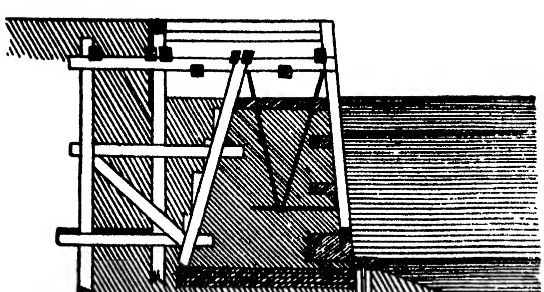


FIG. 5.

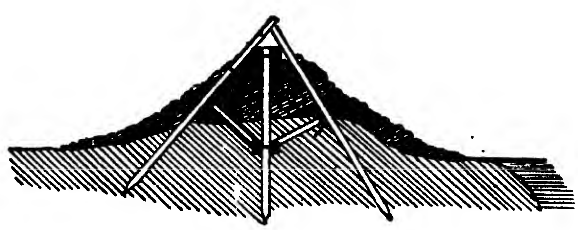
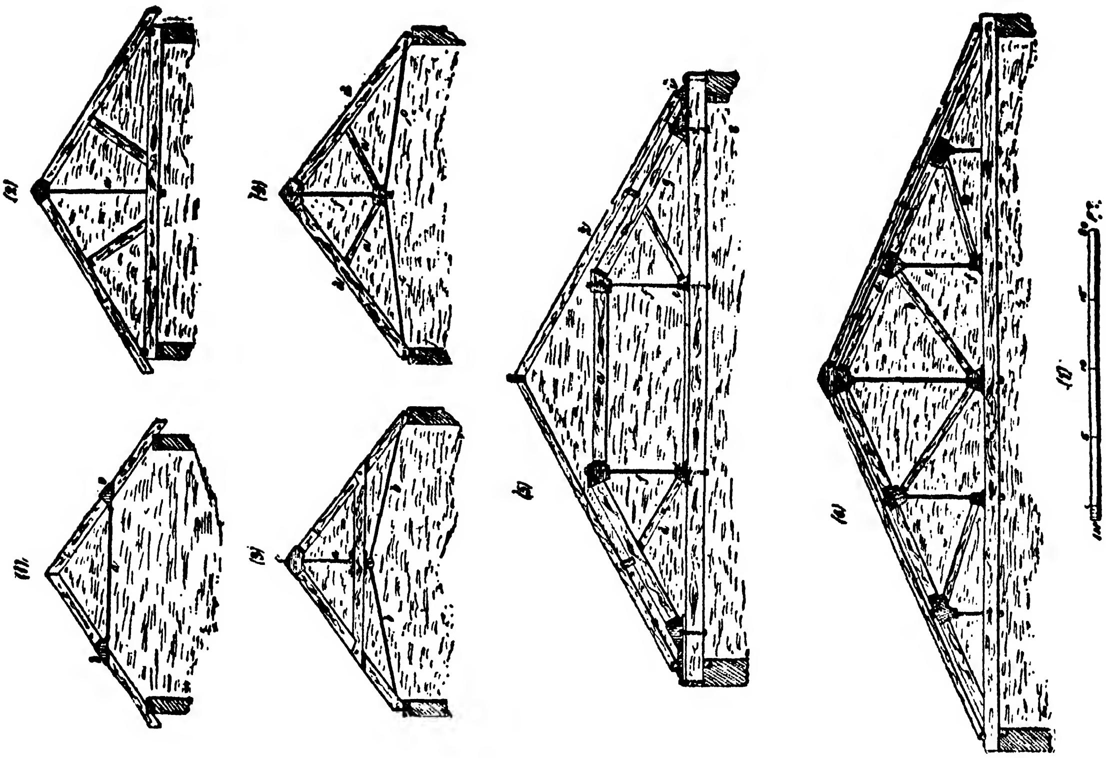


FIG. 6.



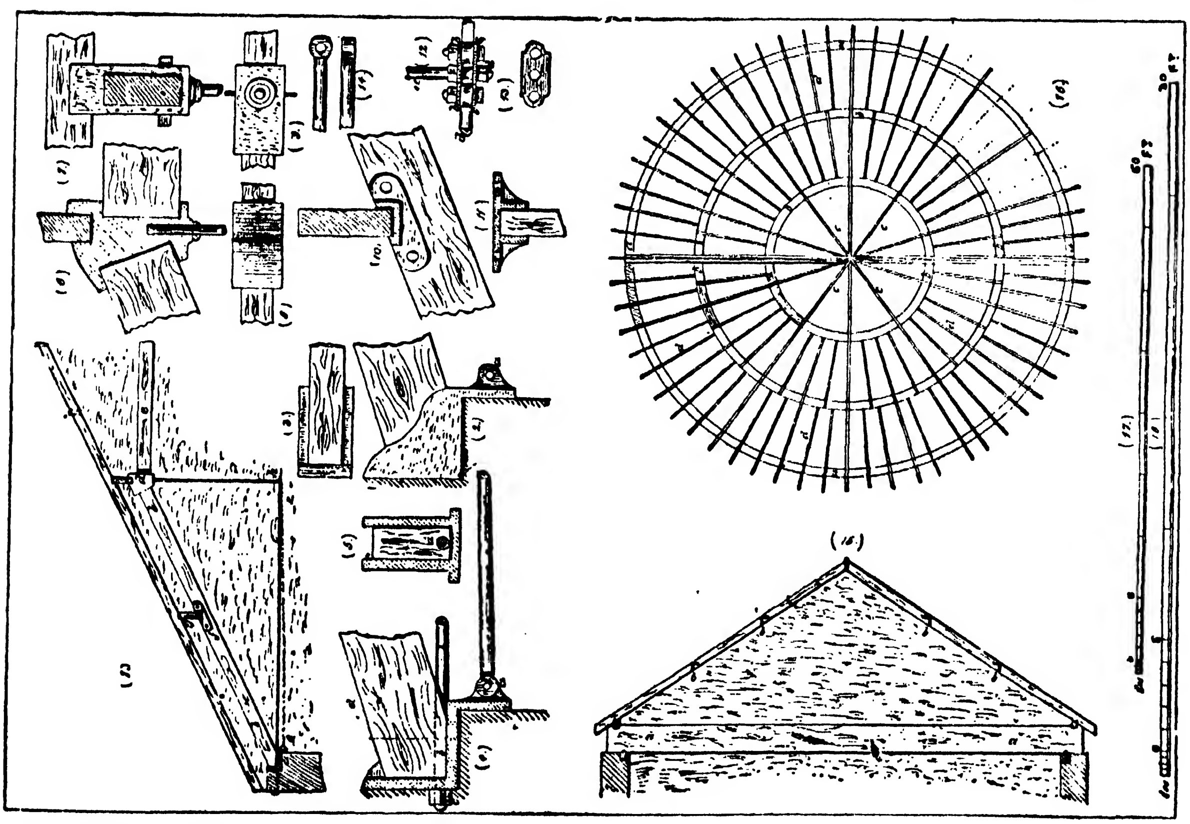


FIG. 1.

STOVES AND FURNACES.

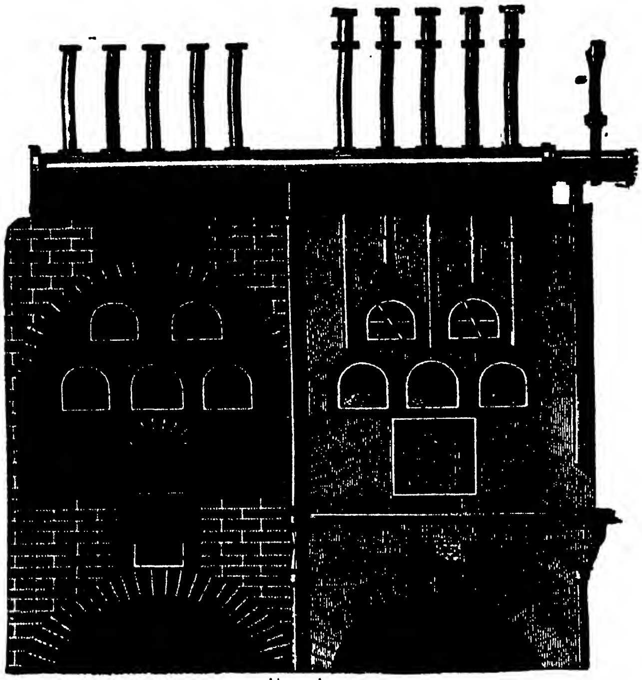


Fig. 1.

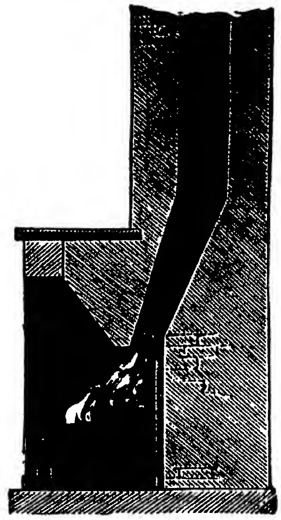


Fig. 3.

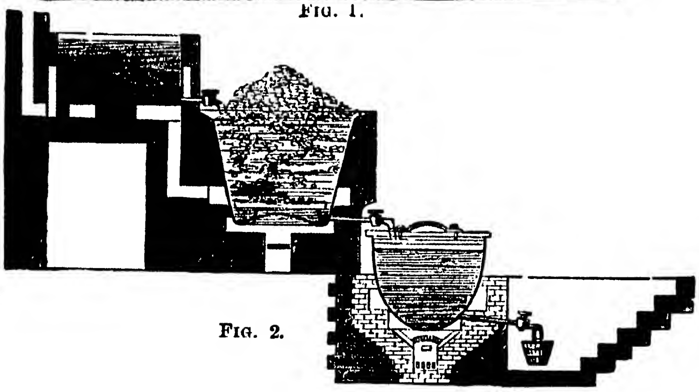


Fig. 2.

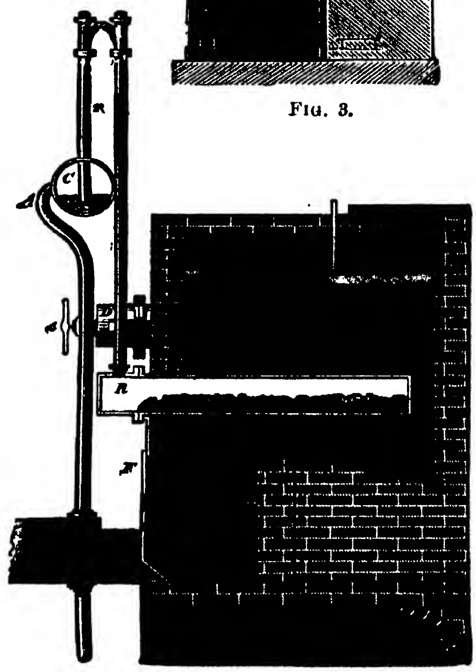


Fig. 6.

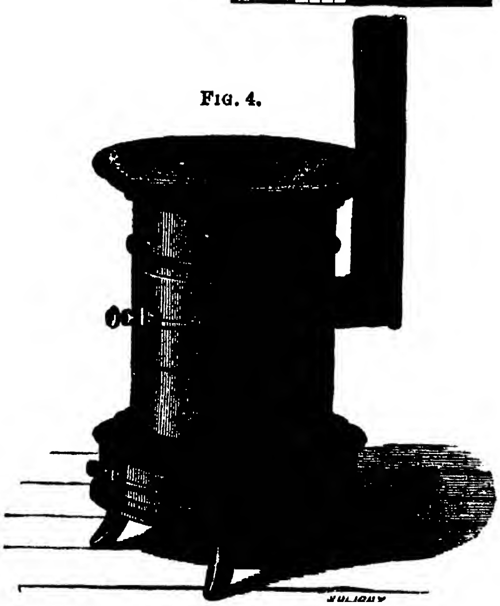


Fig. 4.

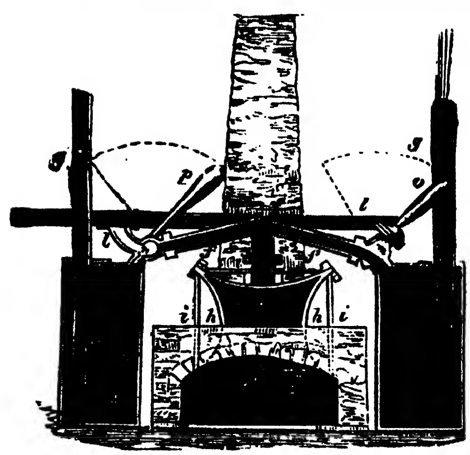


Fig. 5.

THE TECHNICAL STUDENT'S INTRODUCTION TO THE GENERAL PRINCIPLES OF MECHANICS.

LAWS AFFECTING NATURAL PHENOMENA—MATTER AND MOTION.

CHAPTER XXXIII.

In describing the action of the arrow in last chapter, we pointed out that, if merely a pointed rod, while it might penetrate an object if it struck it fairly or end-on, the aim taken with it would be very uncertain; for, however accurate the aim of the archer might be, and however straight the line in which the projectile force of his bow sent it as it left his hand, the course it took would not be in a straight but in a wavy or zigzag line, going first to one side and then to another, the resultant, or what might be called the average of the lateral movements, being a line which would lead to some position aside from the point actually aimed at. And this will be understood if the young student will apply what we have already given on the subject of fluids acting on oblique surfaces. For if the rod were not actually straight, but crooked in the direction of its line of length, as at *c c*, fig. 57 (*ante*), it is obvious that each bend would give an oblique surface for the air to act upon, and with the result, as we have already explained, of creating, so to say, a force which would move the rod either to one side or the other, and to which there would be no equal and opposing force. But even assuming that the rod was perfectly straight, if at any point of its progress through the air it swerved in the slightest degree from the straight course, the length of rod would then assume a position oblique to the right or direct course, as shown at the angle *d*, or that at *e*. And the condition of the barb *b* in relation to the weight and length of the rod *a a* would itself be a disturbing cause, bringing about the change of the position as at *d a e*. And these positions would give of necessity oblique surfaces for the air to act upon, bringing about changing forces. Simple as the means adopted to counterbalance one opposing force with another, and to give a steady straight motion to the arrow in its flight through the air, appears to be, the young student may rest assured that it would be a long period, and only after a patient and sustained observation, which would tend to the invention of the feathered head *f f*, or to the discovery of its useful effect in giving precision to the flight of the arrow. For, simple as is the application of the principle upon which this precision depends, it is as much a highly valuable mechanical invention as the windmill or the propelling screw—which in reality the feathers *f*, *f*, of an arrow are. Those feathers do not project straight from the rod or arrow, as at *g*, but have, precisely like the blades *k*, *l*, in diagram fig. 55 *ante*, a twist given to them so as to present a series of oblique surfaces throughout their length, from the narrow end at which they join the rod to the outer end at which they spread out or diverge from it. And, as in the case of the screw, the obliquity is greatest at the narrowest part. If the student will now consider the condition of an arrow so provided with projecting blades or sails, so to call them, in relation to the air through which it is swiftly projected, he will perceive that the action of the air on the equal and opposing oblique surfaces will result in the rod rotating on its axis throughout its course. For as the air strikes perpendicularly on the oblique surface of one of the feathers, as *f* in diagram fig. 57, at every point on the surface, and this surface moving through the air, the oblique section at each point is pushed, so to say, away sideways from *a* by the force; but as the feather surface is firmly fixed to the shaft or rod of the arrow, this side motion is converted into a partial turning round of the rod on its axis, precisely as if it were fixed to but free to turn in bearings, and the feather surface pushed down by the point of a pencil pressed upon it. And as this pressure of the air perpendicularly on the oblique surfaces of feather *f* is taking place also in those of the feather *f'* on the opposite side of the rod or shaft *a* of the arrow, tending to force it laterally away in the direction opposite to that of the surface *f*, the rod *a*, receiving continuous impulses from the air on both sides, keeps turning or rotating on its axis. And this continual rotation, in conjunction with the continued progress through the air in a certain direction, the result of the force of the bow, completely neutralises any influence which would cause the rod to swerve either to the one side or to the other, as at *c c*, and compels it, so to say, to take the straight course, as shown by the dotted lines central to opposing influences represented by the curved lines on either side of it. The archer, knowing that his arrow will go straight to the point he aims at so far as it is itself concerned—that is, if well made and the feathers properly adjusted—has only to allow for certain extraneous influences, such as the strength of the wind which may be blowing from any particular quarter, and which would tend to carry the arrow aside, either right or left, from the mark aimed at. And it is upon the skill with which the archer estimates and makes allowance for those opposing influences, and notes the peculiarities of his bow or crossbow, that his accuracy as a marksman depends.

Mechanical Points connected with Projectiles.

When firearms were introduced, in which the force of gunpowder explosion in a long and small-diametered tube was that which sent the ball or bullet or projectile through the air, in place of the force of the elastic string or cord of the bow or

crossbow, an altogether new departure in the art and science of projectiles was made. But although the new "arm" viewed as a whole, including its mechanical features and the explosive power, gave enormous advantages to the sportsman or the soldier, it was very long before these advantages became at all fully available; and it is but yesterday, so to say, in the history of science, when it could be said that while the gun or the cannon was an arm of power, it was also one of precision. And this extra and enormous advantage of precision, by which it could be calculated with some degree of certainty that the object aimed at could be "hit" or struck by the projectile sent through the air by the force of gunpowder exploded, was only arrived at when men began to study the phenomena of the feathered arrow, and to give close attention to the principles upon which these depended. As another suggestion of the value of the lessons derived from the working out of or all round mechanical subjects, it may be well to remind the youthful mechanical student that, great an advance in the art of projectiles as the "feathering" of an arrow was, it may be taken as certain that the discovery was either the effect of accident—or as men call it chance—or of one of those "happy thoughts" which come to men they know not how, and which turn out or act when shaped out they know not why, with which the history of practical mechanics abounds. Or if the first suggestion was given to a thoughtful man by his "observing" something which had before been seen or looked at without observation—which, as we have seen, is but another name for thoughtful looking at—probably by generations before him, it would take a long and careful series of observations before the plan of feathering an arrow was completed. And although its action was known, the youthful student may with almost absolute accuracy conclude that it would be long before it was known how the action was produced, or why it must under the circumstances be so. But when once it was understood that the accuracy of the aim of a feathered arrow was caused by or dependent upon the action of the air on oblique surfaces, which caused the arrow shaft to rotate upon its axis, or—to use the popular phrase, which is also the technical one—to "spin," the application of this principle to the projectile of a "firearm" was, so to say, comparatively easy. At first, and for a long series of years, a gun or cannon consisted essentially in a long and comparatively (in relation to the length) small-diametered circular hole, *a a*, diagram fig. 58, made in the interior of the iron cylinder *b b*. In the early "makes" this cylinder was of equal diameter throughout; but in later ones and especially after cast-iron was introduced as the material—as the greatest bursting effect of the gunpowder was produced at the "breech" or inner end of the interior hole or "bore"—the cylinder was made stronger round the "breech," and as the explosive or bursting force of the ignited gunpowder gases got lessened as they travelled towards the mouth or orifice of the gun at *d*, the diameter gradually lessened also, thus giving the well-known tapered or conical form, as shown in the diagram. But in all cases the diameter of the "bore" or hole was uniform throughout its length, so that the sides were perfectly parallel. And to facilitate the progress of the projectile along the "tube," the interior was made as smooth as possible. It was a very long time indeed before machine tools had got to that point of perfection in design and execution which permitted the maker of ordnance to bore out the interior, thus securing a smooth surface equally all round; the avoidance of all projections, and therefore correspondingly created hollows or indentations, being the great object aimed at. The early makers little thought that the time would come when a very decided yet peculiar hollow would form an essential part of a gun or cannon which should deserve the name of an "arm of precision."

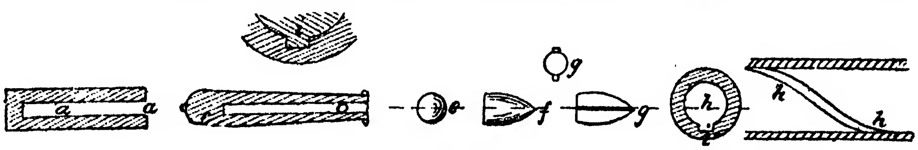


Fig. 58.

As weight or heaviness in the "projectile" to be hurled with swift speed and great force against the enemy was an essential, the young student will see, as he thinks over the peculiarities of the sphere or globe—its surface in relation to its cubical capacity—the reason why the projectile was made, for many a long year, in the form of a ball, as at *e*. It was long before the modern form, shadowed forth at *f*, came into existence. As a "knocker over" of a body opposed to it, the ball *e*, sent with speed and force, was effective enough in its way; but it had no pretension to the office of a "penetrating" and "breaking up" force, such as the projectile shaped as at *f* possessed. And this form followed as almost a natural result upon the adaptation of the "spinning" principle of the feathered arrow. By giving a projectile, shaped like *f* in diagram fig. 58, projecting parts or feathers at the sides, and giving to these the necessary obliquity so as to secure the screw-like twist, when forced or driven from the gun or cannon, a rotatory motion

round its axis would be produced, precisely in the same way as in the case of the arrow, as in diagram fig. 57; and projectiles on this plan have been produced. But objections to a projectile so made will be obvious. It would be noticed, in using the old form of "smooth bore" (so called) gun, that when it was not really smooth and accurately bored, certain irregularities in the path of the shot would be produced, giving the ball a bias in the wrong direction; and even with the extremest accuracy obtainable by the defective machine tools then used, that precision could not be obtained. If by any means the ball or projectile could be made to pass along the interior of the bore not in a straight line—that is, simply driven out along its surface, but so that it would travel round the surface of the bore as it went along at the same time—the result would be a spiral path, the centre of which would be the central axis of the gun, and the ball would have in this case a compound motion as it flew through the air: a motion straight on, derived from the explosive force of the gunpowder; a motion round its axis, derived from whirling round the interior, so to say. If this movement within the bore could be compelled by the way in which the bore was formed in relation to the ball, the "spinning" of it on its central axis would be secured. And this was effected by what was called "rifling" the gun or cannon. The term rifle is derived from the old French *rifler*, or from the German *raffen*, to snatch away, to sweep away; the word "groove" from the German word *graben*, to "groove"; and by cutting the groove in the interior of the bore so that it went round its surface in a continually changing direction, a spiral path or channel was formed, as shown at *h* in diagram G. This channel or groove runs in what is called an easy curve, the convolutions being the reverse of quick or sharp; in other words, the pitch of the spiral is very long. To place the ball or projectile within the influence of this groove, it is necessary that it should have a grip or hold of it: if as at *i*, it is obvious that the ball would simply slide along over the groove, but if furnished with a projecting part, as at *j*, the ball would be compelled to follow the groove, and thus be made by it to whirl round the bore or barrel. In small firearms which are rifled the ball is of lead, and it is made a little larger than the true diameter of the bore; and under the pressure of the forcible ramming down—in the case of "muzzle-loaders"—the lead bulges out and naturally recedes into the groove somewhat, as at *j*, thus giving the ball a hold or grip of it, so that it is compelled to follow the line of groove or "rifling" of the gun or cannon; in the case of "breech-loaders" the ball, a little larger than the bore, is placed in the breech, and the force of the gunpowder explosion drives it out, so that part is bulged out into and takes hold of the groove.

Matter.—Bodies.—Materials.

The youthful student will, by the time at which he arrives at the present stage of our inquiry into the phenomena of bodies considered in relation to what by common consent it is agreed to call their mechanical properties, see clearly that those phenomena are all—to use the only expression which is open to us—created, and are controlled in their various conditions by the two great laws of nature —attraction and repulsion. The student will have also learned, although somewhat contrary to popular notions, that to the varied conditions in which what is called *matter* is met with, the same term *body* is alike applicable, a gas or common air being as much a body as a solid mass of material, like a stone or a piece of wood or a lump of metal, to which the popular mind has no difficulty in applying the term. He will by this time have further learned that the conditions of bodies to which we give the names of solid, liquid, and aeriform or gaseous, are merely relative,—that while one condition is the ordinary or normal one of the body, we may, by changing the circumstances under which those bodies are placed, change their conditions, so that the same body which is solid now can be made liquid, or if liquid be made aeriform or gaseous, and that an air or gas may be made liquid. But while aware that those varied conditions and such phenomena as they present (*phenomen*, from the Greek *phainomenon*, and this from *phainomai*, to appear: phenomena are thus things which have an appearance or what can be seen or "looked at") are all manifestations of the two great laws of attraction and repulsion; still a knowledge of all the conditions in which matter exists, or which it may be made to assume, and still more a knowledge of the limits within which those changes may be made, is what the youthful student cannot possibly be supposed to possess, and what is possessed indeed only by the learned few. And of those it has in truth to be said that, great as their knowledge appears to be, and indeed is, as compared with that possessed by the great majority, there is a point in the investigations of physical phenomena beyond which they have not been able to go; and of what exists or is or may be on the other side of that point they are constrained to confess, all reluctantly though it be—for the pride, and we may say the presumption of some scientific men, is by no means small—that all they know is that they know nothing, and still more reluctantly have to admit that the almost certainty is that they never will know anything. Nevertheless, though this be the case, and it is well that all scientific men should be what the true scientific men—the followers and disciples of Bacon, of Newton, of Faraday—always are, humble, what men do know through scientific men having found it

out is in its amount so great, and in its characteristics so valuably practical, that we owe to it all we possess in the way of work actually done, material wealth and prosperity secured. And although there be a limit beyond which it is not ordained by an All-wise Creator that man should go, that limit is so far beyond what man has yet reached, that the truths yet to be made clear, the facts known, the phenomena displayed, are likely to be as infinitely more numerous, as they will be more beneficial to man, than those hitherto found out and exemplified have been. And with a field so vast lying still unexplored before us, and with a potentiality of utility beyond the dreams even of the most sanguine, one would indeed be foolish to waste time in vain regrets that there is a region beyond into which it seems destined that man shall never enter; still more foolish that, this being so, he will not work in the field he has at least possession of, because there is one which he is never to get. What men have done before him, what they are doing now, the young student can do also; or, if he cannot compass work of the same high character as that they have succeeded with, he can at least do something which will be useful to himself, if not to his neighbour, —and for the matter of that no man can do well for himself without benefiting in some way his neighbour. By dint, therefore, of that close and careful observation, on the value of which to him in his daily work we have already drawn the attention of the young student in mechanics, and with the added all-essential element of equally close and careful thought—thinking things out, thinking them all round—he will be able to acquire a knowledge of the peculiarities and what may be called the mechanical values of materials, of the greatest use to him in his daily work and practice. We have said that the conditions in which substances—or to use by way of preference the better term, materials—are met with are purely relative; that is, they are dependent for their peculiarities, for the time being, upon the relation which the natural laws have to them. But it is a fortunate thing—we prefer to say that it is a well and wisely ordered condition of Creative Wisdom—for man that the normal, ordinary or natural condition in which what are called the materials used by the mechanic is precisely that condition which fits them for his purposes. Thus, although we have in a mass or heap of granulated material the very same constituents of which a mass of freestone or of granite is composed, it is obvious that for all the ordinary work of the mechanic the sand or granulated condition would be of little use to him for constructive purposes, and it is only when the same substances or constituents are in a state or condition of coherence—that is, in which there is that close "cohesion" between the particles—that they are valuable for those practical purposes. And it is this condition—relative though it be nevertheless to the controlling influence of certain natural laws—which is the normal, ordinary, or, as men phrase it, the natural one in which the constituents of stone are found. Again, though a mass of iron in a melted, molten, or fluid condition is precisely the same as regards general constituents or particles as the mass of iron in a solid condition, still it is obvious that for the general purposes of the mechanic this molten state would not be useful. But the widest range of purposes is at once secured by the ordinary, normal or natural condition in which the iron constituents are found—that is, in their solid state. But the thoughtful, though it may be the youthful student, will perceive the value of the very fact involved in what we have said as to the relative condition of materials; for it gives to man the power so to avail himself of natural laws that, by certain modes of applying those, he can change the condition of materials so that the very changes will conduce to his convenience. We here only allude to this in a general way; but in noticing, as we are about to do, a few of its leading characteristics, the student will see its enormous value to the mechanic—a value which it is impossible to overestimate. This controlling power, so to call it, exercised by natural laws brought into operation in certain ways, is that which modifies the conditions of all materials, and brings into existence all their characteristic features. And the youthful student who is only beginning to investigate the materials he has to deal with, the more closely he carries on his inquiries the more startling will be his discoveries; the more clearly will he see that what at first sight seem to be fixed and unalterable conditions of materials are merely what may be called temporary, and may be so altered as to place within his reach uses for the materials of which at first he had no conception. It was remarked, for example, by a profound thinker that weeds, which farmers look upon as the pests of the land, served a useful purpose. In this he did not so much refer to the fact that some day science would show—as he believed it would show—that the weeds which grew so readily had in themselves a very high value for some purposes of which at present we had no conception, as to the fact that, growing so freely, they compelled good farming; for the best methods known to the farmer to get rid of them are precisely those which improve the soil and facilitate the good growth of the crops which the farmer desires to cultivate. In like manner it may be said of the materials which the mechanic has at command, presenting features in their natural or ordinary condition which have to be got rid of before they can be made available for certain purposes, or to be so changed in character that new properties are given to them by the mechanic.

THE GRAZIER AND CATTLE BREEDER AND FEEDER.

THE TECHNICAL POINTS CONNECTED WITH THE VARIETIES OR BREEDS OF CATTLE—THEIR BREEDING, REARING, FEEDING, AND GENERAL MANAGEMENT FOR THE PRODUCTION OF BUTCHERS' MEAT AND OF DAIRY PRODUCE.

CHAPTER XXVI.

IN discussing the subject of succession of grazing fields in use, begun in last chapter, we observed that by the arrangement described, the system formed a cycle always returning into itself, the fields being in a condition of continual advance, beginning say with No. 4, passing up to No. 3. From No. 3 they pass up to No. 2, when they reach the rank of first class, or best stock ready for market, or to be finished off with house or box feeding with artificial food and soiling. The field occupied by them when they are taken off it is thus passed to the position of No. 1, where the grass is allowed to grow. The length of the period during which this growth is permitted to go on will depend upon a variety of circumstances,—such as the quality of the soil and of the grasses, the manurial condition, and the style of culture adopted, as well as the character of the climate and also the locality. For in regard to the latter point the grass of a field will grow more quickly and thickly where the field is sheltered from than where it is exposed to cold, biting, or persistently strong winds. In some districts, and with a good and carefully carried out system of cultivation, a few weeks will give a fuller " bite " of grass—that is, a stronger crop—than months will give in another district, and with a bad or indifferent system of culture. While climatic and local circumstances are important factors in the problem of grazing, it should be borne in mind, as a fact most encouraging to the practical man, that the untoward influences of climate and locality can be greatly modified and improved by a carefully carried out system of cultivation and general management. We have abundant evidences of the truth of this in several districts of the kingdom; some of which possess a much higher condition of farming, although with a bad or untoward climate and poor soils, than other districts where, with a much better climate and soil, cultivation is careless and good systems comparatively unknown. The inexperienced reader will note that we have coupled a good system with its careful carrying out, as marking two essential things which are yet different, though they are frequently looked upon as one and the same thing. This they are not, for one may possess a good system, yet it will be of little service if not well and carefully carried out by him.

Habits of the Animals themselves, as greatly influencing Management of the Grazing Fields.

How carefully the grazier must carry out his business, and how many are the circumstances constantly demanding his attention if he desires to be successful, we have to some extent, in preceding paragraphs, shown. But we have not yet exhausted all the points to which his attention will be required, and should be given. It will not be enough that he makes the best of his land by careful and good cultivation; that he chooses with judgment the breed of stock best adapted to his land and locality, and selects with skill the best specimens of those breeds. His powers of observation will be called into continual requisition, by which he will be able to discover many points connected with the habits and peculiarities of the animals he possesses, which, if attended to, will contribute in no small degree to his success as a grazier. The very point which in last paragraph we were considering—namely, the length of time given to the pastures to recover, and afford a good "bite" for that which previous feeding off has taken from them, is in itself influenced by the habits of the animals which are to be grazed on the fresh-grown fields. The point may not have suggested itself to some, but each animal has its own peculiar way of eating, its own likes and dislikes as to the character of the food. Let the inexperienced reader observe a cow at feed, and he will perceive that it uses its tongue in a curious and singularly effective way in drawing, as it were, the grass into its mouth. The teeth are not the direct and immediate instruments, as in the case of the sheep, which, observation will show, use their teeth directly in nibbling at the grass. A close short sward will thus afford a good bite for sheep, as also indeed for the horse, which will be a poor one for cattle and cows. A good length and fulness of grass is therefore essential to the quick and steadily progressive fattening of cattle or of cows. True, they will find food in a poor short-sward field, but it will be found only at the expense of their condition; and if they have the choice, they will feed only off the grass best suited to their habit of eating, and hunger alone will drive them to eat off land which gives grass unsuited to their habit; and the reader who has paid attention to what, in a preceding chapter, we gave on the habits of animals, and how these ministered to their good fattening or feeding, or the reverse, just as their habits were or were not attended to, will here perceive that if cattle are compelled by short supplies of food, or if food be comparatively plentiful, but is in that short condition of growth or of that quality which does not suit their style of feeding, they cannot possibly make rapid progress in fattening. Hence the absolute necessity to see that the pastures have sufficient resting-time to acquire that growth of grass known technically as a "full bite." We have said that this will depend upon the circumstances we have named, to which also this other

must be taken into account—namely, the season of the year; for it is clear that growth will not be so rapid and full in the winter months as in those of high summer. Some graziers arrange the management of their pastures so that, with the four-course system we have in this chapter described, the whole year is divided between the four sets of fields: thus, the field or fields which are begun to be eaten off in October are pastured throughout the winter more or less continuously according to the state of the weather—which may be "open" or, on the contrary, very severe, and up till March. Fields set aside to rest or grow—technically called "laid"—at the end of February will be ready to be depastured about May. Those laid in the latter month, indeed, requiring now a shorter time for a full bite to be obtained, will be ready to be grazed as early as June; and those "laid" in this month may be ready for pasture, if the season be a good one, by the middle of August; while those laid in this latter month will be ready for the October grazing,—thus returning to the same period of the year at which the system was started. Those periods here named are not, of course, to be taken as absolute, even in the same locality, one season after the other; for it will be found that in almost every season circumstances will crop up which will demand a modification of the general system. But what we have given will convey to the reader a fair notion of the principle upon which the system of field or pasture management is based; taking care to remember that attention will be perpetually demanded from the grazier to find out, so to say, what those circumstances are which demand some modification of the system laid down.

Pasturing of Sheep with Cattle.

We have already referred to the demand which is made on the powers of observation of the grazier by the varied circumstances of his practice, and alluded to more than one point as illustrative of this. This may be further exemplified by a fact which the grazier will find in his practice as closely affecting the system on which his pastures are to be managed. We have already noticed that the different grasses and plants—these latter not grasses properly defined —are differently favoured by different animals of the farm, the favourites of one being disliked by others. This fact it is which decides the grazier to have his fields pastured not by one class of animals alone, such as cattle or cows—which would of course only feed off that which they liked—for the proverb is well illustrated in such a case "that you may take a horse to the water, but you cannot make him drink." Hence sheep are turned in along with cattle and horses in some cases. The sheep will find abundant food in the short grasses, which they can nibble at with their teeth, but which the cattle and the cows will pass over, as they are too short to suit their habit of eating. The plants, moreover, which grow spontaneously, natural and to the soil, which are left by the cattle, are discovered readily by the sheep. But there is more than this in the point we have under notice in modifying the system of pasture management; for it is found in practice that the very same grasses and plants which animals will eat at one period and thrive upon will be shunned by them at another period. Why, we do not know; but it is facts with which we have in life to deal, and this is a fact which must not be overlooked by the grazier. So that even if he pastures with one class of animals only, he must not decide that he will thus have all his fields equally fed off. But if deciding, in view of what is here said, that the best plan will be to have his fields grazed with a variety of stock, he should have this important point also in view,—that as quiet is essential to rapid and economical fattening, this quiet is almost certain to be disturbed, more or less, by the practice of putting up animals of different kinds; for while the habits of one class will dispose them to feed or be at rest, those of another class will incline them to be playful, or, as is often the case, wantonly and mischievously disturbing. Nor is this inequality of disposition noticeable only in animals of different kinds, for it is not seldom manifested in stock of the same class. This is especially seen in the case of young stock pastured with older animals. While some old cattle show a positive liking for not merely one another of the same age, but for young animals, which is in many cases most touching and expressive, some will persecute young stock to a very painful extent. This is very noticeable in the case of pig feeding—and more noticeable perhaps because they are more under the eye of the feeder than are cattle or sheep pastured in a large space; but not seldom, where the feeder has been careless, have pigs been nearly—in some cases quite—starved to death, from some older and stronger pig beating them off from the feeding trough. The truth is—although it is not very palatable to man, who is apt enough to consider that he is in all things the superior animal—that animals are in many respects very much like ourselves; they have their own characters, their likes and dislikes; some are gentle and good-natured, others are peevish and cruel. And the grazier who is most successful in his practice is he who looks to all points connected with it, and does not disdain to consider that his animals are something more than the mere machines or media by which he can convert food into flesh, which some graziers seem to think they are. In the lower as well as in the higher aspects of the question, the truth of the Scripture saying or text is abundantly verified: "The merciful man is good to his own soul; but the cruel man troubleth his own flesh."

THE MACHINE MAKER OR GENERAL MACHINIST.

SPECIAL EXAMPLES OF HIS WORK—ITS LEADING TECHNICAL PRINCIPLES AND DETAILS.

CHAPTER IX.

REFERRING to the statement made at end of preceding chapter, that to *know* a subject is the legitimate, the only true end of all study, this brings us at once fairly in front of the various considerations connected with the practical education and training of the machine maker or general machinist who has to gain his livelihood by his work, to the essential importance of which we have already alluded. The tendency above noted of the mere student of machine science—and it holds equally true of other sciences on which practical trades are founded—is so far as it goes based upon a correct estimate of what science is, but it does not go far enough. It stops short of just *the* point which gives to science its truly practical value—in one sense its only practical value—namely, that which makes it available in the actual work of daily life which has to be done, and to which work the science is adaptable. Taking the strictest view of the case, it is quite true that the science of any subject is simply the knowing what that subject really is. The very term "science," or rather the derivation of the term, indicates this—it being derived from the Latin verb *scire*, to know, our word science coming directly from the Latin *scientas*, and this from *sciens*, the present participle of the verb: *scientas*, "knowledge." And it will be a fortunate thing for the student merely as such—we may here remark, and the remark may be taken as a grave hint or warning—if he always bears this derivation of the term science in mind. If he does he will be saved the mental disturbance, and, what may by some be considered of greater importance, the loss of time which would be the consequence of his giving heed to those "will of the wisps" called "theories," as to points connected with the science of machines—theories which are based, or attempted to be based, upon what are in reality fancies, inasmuch as they are not facts, for facts are things arising from what we "know." And those theories we have alluded to, and to which not a little—we frankly confess to feeling too much—attention has been paid of late, are based upon, or depend for their so-called truth upon, what may be "conjectured," but which from the nature of things can never be "known." Now, true science—and, as we have seen, the word means but one thing only—has only to do with what is known, or with what can be known; it in no wise troubles itself with what common sense, indeed, tells us cannot be known—at all events is not, with our present condition in relation to nature and her laws, capable of being known. This condition may be changed, but till it is so the man of true science deals with facts only—things known—not conjectures which are mere descriptions. And it is this true science alone which has given us all we possess in the thousand-and-one mechanical aids or helps in the doing of our daily work in all its varied and ever-varying work.

"Work," in its Special Application to Practical Mechanics.

But it is this very element of *work* which makes the practical education and the training of the machine maker or general machinist something more than merely knowing—the science is, of course, essential, and this is not likely to be denied in the present pages at least—but there is a vast deal more required before the student can be trained or made into the successful machine maker or machinist. A man may know, and thoroughly, what his work is, and upon what it is based; but this knowledge comes to be of real use to himself and to his fellow-men only when it is applied to the actual *doing* of his work; and this doing obviously implies that he knows *how* to do it. And it is in the "how" that the difference lies between the man who is successful and the one who is not. And with this "how" not one, but several things, are concerned, and these form as much an essential part of the practical education and training of the machine maker and general machinist as *knowledge* that is an acquaintance with the *science*. That this is in every practical sense true, every practical man knows. There is not one who has had a wide experience of what the work of the machinist is, but is convinced beyond a doubt that that work will only, can only, be successful when the various points which influence true success are secured by the practician. And it is of little use, seeing we have to deal with facts in this world, to ignore all those points which go to secure a knowledge of the "how" to *do* work, to say that because they are not in the ordinary sense of the term scholastic, or, as we might perhaps in a clearer way put it, because they do not form part of the usual course of study in the technical class, or are made special points of in special lectures, therefore they should not be noticed in a special treatise like this. The very fact that these points connected with the "how" to *do* work, which every man of practical experience in work knows to be absolutely essential to success in the doing of it, do not form part of scholastic study, or what is now called a "course of technical education," is to our minds the most urgent of all reasons why we, at all events, ought to draw special and earnest attention to them. They either do or do not exercise a very powerful influence upon the success of the general machinist: if they do, then all the more reason for drawing here the pointed attention of the technical reader to them. And this we venture to maintain:

that there is not a practical man who knows what work is, and can do it, who will assert that the points in the "how" to do work we have alluded to are not essential. They know, what is the actual truth in the world of work, that true success cannot possibly be obtained without attending closely to these points. And by the word success we mean not merely the business or trade success involving the making of a good living, or of money, but in the designing and the constructing of machines which give the best work in the cheapest way. The machinist in his study may get along well enough without taking into consideration "men" and "materials," but in his every-day life and work he will find that they constitute very hard and striking facts, which, if he would, he could not dispense with, and would be wrecked, so far as success in life and work is concerned, if he tried to dispense with them.

The Power of Observing an Important Factor in the Training of the Machinist.

Viewing the great truth that all the work which has been done in the way of devising and constructing machinery has been based upon facts—that is, objects existing, and the laws which govern the various conditions in which those do exist, or are, both the objects and the laws which govern them being capable of being "seen" and "known"—he who first stated that mechanical engineering might be defined as the "science of observation or seeing" hit upon a definition which conveys, if not the whole of the truth, at least so very much of it that it may be accepted as practically true. And its practical truth is corroborated by the experience not only of the present day in mechanical work, but by the whole of the experience of the past, since the period when man discovered and availed himself of those helps in the doing of his work to which the name of mechanical is generally applied. By this term every one, even the traditional schoolboy, knows that it is something which is added to the primary means of doing work—namely, the hands—by which the manual labour, in this case truly so called, is aided, and the power of the body, or of some other power, as that of wind, water, steam, or electricity, can be applied to the performance of a greater amount of work than the mere hands could accomplish. Like many other epigrammatical definitions of practical or of technical work, this, which makes mechanical engineering in general, and (as the greater includes the less) the work of the machinist, to be in fact the science of observation or of seeing, has no doubt an element of exaggeration, or what may even be called paradox in it. But he who first used it must have had abundant reason to know the value of the great practical truth which is embraced within the terms of the definition. And if it was true in the earlier days of the profession, it is still more pregnant with truth in the times we live in. And these times possess this curious characteristic,—that while the field of observation is now, as compared with that existing but a few years ago comparatively, enormously extended, and this through the great accession of examples of practical work, the very number of the special applications to almost every branch of industrial work would seem to preclude the possibility of finding out new, or of widening the application or improving the details of old inventions and work. In other words, engineers of late years have done so much that it appears at the first glance of the whole subject that little remains to be done either in the way of discovery or invention of new or the improvement of old and established work. But if this appears to narrow the field of observation, it makes the necessity to exercise a keener and closer observation all the greater. But this straitening of the boundaries of work is only apparent; in reality it is all the more widened. For, as exemplified in many subjects treated of in the pages of this work, it is a peculiarity of a new discovery or invention that it gives rise to the creation of new machines and appliances, which are necessitated by the very requirements or demands of the new department. It would be easy to cite instances of this other than those alluded to more or less specifically in our pages; but those of our readers whose practical connection with the work of the profession has extended over but even a few years must have had within the range of their experience more than one example of the striking truth of the characteristic of what we have here advanced. A characteristic so striking, and apparently so attached to all progressive movements in the art, that it may be said with almost absolute accuracy that there is no new discovery or invention which itself creates what may be called its own primary machinery, but what requires more or less speedily the application of other machines or mechanical appliances to supplement it and make it more or less perfect. The field, therefore, of observation, in place of being narrowed with reference to the creation of new and of better work, is absolutely just all the more widened. And this not merely in the sense that because examples of work are now so multiplied there is a vast addition to the objects to be observed, but in the very much higher, and for the purposes of life much more practical sense, that the demand for further work is just so much the greater. The truth of this position will not be disputed by those who know what the profession has been in past and now is in present times.

THE BRICKLAYER OR BRICKSETTER.

The Principles and Practical Details of his Work

CHAPTER XVI.

In continuation of the method of setting out brick arches, as illustrated in fig. 5, Plate CXXIX., and commenced in last chapter, we have to say that the arc *h i* is to be bisected in the point *j*, and from *j* a line drawn to point *g*: the part *g k* of this is one of the joints of the arch. To find the next lowest joint, from point *f*, with any radius, describe the arc *l m*, cutting the lines *m f d*, *l f c*, drawn through *f* to centres *c* and *d*. Bisect *l m* in *n*, and draw *n f*; *f o* is the next joint. The next is found in like manner, by drawing from the point *e* the lines *e c*, *e d*, extended beyond the extrados as before, describing from *e* as centre any arc, as *p q*, dividing it in *r* into two equal parts, and drawing *r e*, *s e* being the joint.

Another and strictly mechanical way of finding the joints, which will have a direct relation to the curve at the various points, is also shown in fig. 5, Plate CXXIX. Take any flat ruler or straight-edge and mark off its edge, the two points *t*, *u*, giving a distance equal to *a v*, which is half of the span or width of the arch. By making the two points, as *t* and *u*, always coincide—first *t* with one of the divisions in the intrados *a c*, marking off the brick thicknesses, as *t v w*; next the point *u* with the centre line *b v x*. A line drawn along the edge of the straight-edge will give the line of joint as *t y*. The next, as *v z*, is obtained in like manner by making *t* and *u* respectively coincide with point *v* and the line *b v x*.

The methods illustrated in figs. 3, 4, and 5, Plate CXXIX., give joints which make the ends of the divisions at the extrados of the arch wider at the ends than at the ends nearest the intrados. This must indeed necessarily happen in all forms of arches in which diverging lines are met with more or less pronounced. Thus, while the end *f e* in fig. 5, Plate CXXIX., is the thickness of a brick, the end *o s* is greater than this. Now, as a brick is uniform in thickness, when two are laid together to suit diverging lines, as *o f*, *o s*, the outer ends must be separated, as shown at *l h m* in fig. 3, Plate CLIV. Thus, let *a b c d*, fig. 3, Plate CLIV., be the edge of a brick—that is, showing its thickness, which is of course the same at the end *a b* as at *c d*. Now, if the shape of the part of the arch between two lines of joints—say, such as *e s*, *f o*, in fig. 5, Plate CXXIX.—be such as shown by the letters *a e c d*, fig. 3, Plate CLIV., then it is obvious that the part to make this shape complete, which is lacking, as we see, in *a b c d*, must be made up by some body or substance indicated by the wedge-shaped dotted part *c b e*. This substance in practice is the mortar or cement. This is further shown in the lower part of the diagram in fig. 3, Plate CLIV., which represents in an exaggerated form part of a brick semicircular arch,—here the parallel-sided bricks being placed at their inner ends, as *i f*, *i k*, quite close to each other, must have their outer ends separated, leaving angular spaces shown by the dotted parts representing the mortar or cement. It is obvious that this defect is more pronounced in a small curved arch than in a large one. Where good cement is used, such as Portland, and which will set as hard as the bricks themselves, good solid construction will nevertheless be secured. It is needless to say that this defect in the setting of brickwork arches inherent in the very nature of them from the unvarying size of the bricks, is a serious evil where bad mortar is used for filling in and making good the joints. With this it is impossible to get anything like a solid arch. As we have already said, bricks are often cut or rubbed so as to assume somewhat of the form indicated by the setting-out of the lines in the methods we have illustrated. Thus, a brick may be cut so as to take the form as at *o* in fig. 3, Plate CLIV., and two placed together as at *p* and *q* would fill in the space of the shape shown—though here there would be a joint shown in outside or fine work. The dotted lines in *o* and *p* show the brick-on-edge view complete.

Ornamental Brickwork.

In the preceding chapter we have discussed the subject of brick as a building material as contrasted with stone. We have also explained the principles upon which the practice of bricklaying or bricksetting is based, and have illustrated and described the methods in use as applied to walls and other structures, these embracing that important department of what may be called ordinary or plain brickwork. We have now to follow all this up by glancing very briefly at the next department, ornamental brickwork or ornamented brick construction.

This the reader will observe is to be distinguished from architectural effect, or what is popularly and in one sense correctly enough defined as architectural or building design. This may be obtained by the use of brickwork, as it is secured in the employment of stone, simply by the arrangement, plan or design of the building, which will give an elevation or external appearance which will be pleasing to the eye. But while this gives the element of architectural effect, or what we call design, it gives it solely through the medium of the general mass—the surfaces of the material employed being perfectly plain, that is, devoid of what is generally known by the name of ornament. Of this element of ornament, the building, whether of brick or of stone, may be perfectly or absolutely destitute. It is not necessary here to enter into an explanation of what constitutes ornament; what can

be said of it will be found in the series of papers entitled "The Ornamental Draughtsman," "Form and Colour as applied to Decorative Design,"—and with reference to certain special subjects, such as the work of the cabinet maker, the worker in iron, wood, and stone, in the papers entitled "The Cabinet Maker" and "The Ornamental Worker in Wood, Metal, and Stone." All that is necessary for our present purposes is to point out that anything added to the otherwise plain surface of a mass or body of material employed in the construction of a building, which gives a certain arrangement of lines straight or curved, or a combination of both, is termed ornament. This added attribute to building material of any kind may either be applied at isolated parts of the structure, at intervals greater or less in amount, or be applied to certain parts in continued line or mass. This effect of ornament may be obtained in various ways: either by giving to an otherwise plain surface in the sense of its profile or section a certain contour, form, shape, or configuration, as instanced in what we call a "moulding" (see the plates in "The Ornamental Worker in Wood, Metal, and Stone"); or it may be spread over the whole surface, as of a block, or the united surfaces of a continued series of blocks, in the form of decoration known as "relief," that is, projecting from the surface, and produced by the art of carving; or it may be produced by purely surface effects, either of arrangement of coloured surfaces or by surfaces specially filled in with designs exhibiting straight and curved lines, or a combination of both, and which are produced by the arts of the ornamental draughtsman or of the painter.

Any one of these effects, or all of them in combination, when applied to a built structure, are in technical work said to constitute construction ornamented. But this effect, which is thus obtained by decorated material, may be, and often is, applied to structures which have no pretension to be so considered, and in reality possess none of the features of what constitutes architectural effect or design; although *per contra*, as we have seen, a structure may possess much of this latter effect, and strike the beholder with a sense not only of fitness for the purpose for which the structure has been built, but of beauty, grandeur, and even of sublimity, without possessing any one of the attributes obtained by the use of what we call ornament or decoration.

From the very nature of the material, or rather from the form in which the material is universally made, differing as it may and does differ in different districts and countries in dimensions, brick is not capable of being dealt with or manipulated and worked in the way stone is. Stones employed in building can all, with greater or less ease, be cut by tools so as to give to blocks of indefinite size and possessed originally of plain sides at right angles or oblique to each other, certain contours or profiles which will give them final forms which are truly ornamental. And stones can be quarried and cut into such bulky masses as to give wide, indeed comparatively large expansive surfaces, upon which designs in relief can be cut or carved. Stone, then, lends itself with, on the whole, wonderful ease and ready adaptibility to the purposes of ornamented or decorated construction. Hence, in all buildings in which ornament—using the term in its ordinary sense—is an attribute or peculiarity to be added to the effects produced by architectural design proper, stone is the material employed. What can be done in treating it ornamentally or decoratively, there are abundant examples of everywhere around us. Whéther all these are examples of what is pure in architectural taste is another question, on which the reader may find some remarks of a more or less suggestive character in one or other of the papers referred to in this chapter, or in that entitled "The House Planner."

Brick, unlike stone, is not capable of being specially cut so as to give an ornamental form to its section, nor provided with ornament in relief on its larger surfaces: it is too hard and generally too brittle, and of far too small dimensions, to be so treated. Ornamentation or decorative effect, then, in brickwork has to be obtained in a way or ways specially applicable to the peculiarities of the material; and these, from its very nature, are limited both in number and in scope. So far as form, profile or section of bricks is concerned, something can be done so that certain decorative effects may be produced by their use, either singly or in conjunction—generally the latter. But what has been done, at least in this country, has been very limited in character and scope. The chief of the forms used here and on the Continent will be presently illustrated. If we wish to see of what forms individual bricks are capable, and how decorative effect can be obtained by their combined use, we must go to the Continent. It is there that the finest construction in brickwork is to be met with—not merely in the smaller structures of domestic life in town or country, but in the gigantic buildings of a public character, chiefly in churches. But while examples of fine work done in our own day can still be met with, it is to the works of the old bricksetter we must go, to become convinced of the truth that brick is a material as capable of giving high architectural and decorative effects as it is one which gives construction of the strongest and most durable character. Of late years a good many forms of bricks with decorated or ornamental profiles or sections and surfaces have been introduced. As before stated, they are much more frequently met with abroad than with us; still even here their use is spreading.

THE CALICO PRINTER.

THE CHEMISTRY AND TECHNICAL OPERATIONS OF HIS TRADE.

CHAPTER XXI.

B. Blue Artificial Colouring-Matters.

1. *Alkali Blue* ($C_{38}H_{30}N_3SO_3Na$).—This dye is a magnificent sky-blue, of almost identical shade to ceruleine blue described below. It is fixed upon cotton by means of alumina and arsenic, but is not fast, being destroyed by alkalies, soap, and by daylight.

2. *Ceruleine Blue.*—This blue is sold in the form of a paste, containing 10 to 15 per cent. of solid matter. It is a smooth thick deep-blue paste; the colouring-matter does not dissolve in water, but is readily soluble in alcohol and in acetic acid. It is fixed by means of alumina and arsenic, yielding the brightest of pale sky-blues obtainable in printing; but which, unfortunately, readily fades in sun or daylight—a few hours in the former or days in the latter being sufficient to destroy very pale shades. It is very largely employed—in fact, for all pale blues which need not necessarily be fast to light (in which latter case methylene blue is employed). Ceruleine blue is exceedingly fast to soap and dilute acids. It is manufactured in greatest perfection by Messrs. Roberts, Dale and Co., of Manchester, and by several other firms.

3. *Methylene Blue* (Patent).—This beautiful dye is one of the fastest of aniline and the only fast bright aniline blue. It is manufactured as a dark brown powder, soluble readily in water, alcohol, and acetic acid. It is fixed with tannic acid, with which it yields a very beautiful shade of blue, possessing a greenish hue. This colour is very fast to soap and light, and is now very largely employed, both in this country and on the Continent, for pale shades of blue. With alumina and arsenic an exceedingly brilliant shade of blue results—blue similar to that yielded by ceruleine, etc., but which is quite loose both to soap and light, and seldom employed. Methylene is a patent of the Badische Anilin Fabrik, who are, we believe, sole makers.

4. *Navy Blue, Royal Blue, Mauve, and Green Mixture.*—When aniline violet or mauve is mixed in certain proportions with aniline green a fine deep indigo-blue is obtained. Various mixtures of these two colours are sold under different names, which yield blues differing in shade according to the proportions and to the qualities of violet and green used. The blue is much in use; it is very fast, and is an excellent and favourite shade. It is fixed with tannic acid.

5. *Indophenol.*—This is an interesting dye recently discovered by M. Witt during the course of an elaborate series of investigations upon it and allied organic compounds. It is sold both as a paste, containing, we believe, about 25 per cent. of colouring-matter, and also in a powder. It dissolves in alcohol and in acetic acid to a deep-blue solution, but is insoluble in water. When acted upon by reducing agents, especially acetate of tin at 60° C., it is reduced to a grey or white substance, which is soluble in water; when this is printed on cloth along with an acetate of alumina mordant it penetrates the fibre of the cloth—being soluble—and when oxidised by exposure to the air, to steaming, and to a bath of bichrome, the reduced colour oxidises into a fine deep-blue insoluble dye, which is firmly deposited in the fibres of the cloth. When the colour first came out it was largely used, but since then its use has decreased owing to its sensitiveness to oxidation causing it to oxidise at one time to a shade of blue darker or paler than at another time under but slightly altered circumstances. We hope, however, that the objection to the use of this interesting compound—so analogous in its reducing and oxidising properties to indigo—by future improvement, either in its manufacture or in the method of its application, may be removed, and the promising prospects which seemed in front of it on its first discovery may be realised. Indophenol is manufactured by the eminent firm of Leopold Cassella & Co.

6. *Galloczanine.*—This is another interesting new colouring-matter. Like indophenol, it is met with in the market both as a paste and a powder, the latter of deep chocolate colour. It is soluble in alcohol, and yields with acetate of chrome mordant a fine deep violet-blue. With other mordants it yields varying shades of blue violet; with quercitron bark it gives a beautiful olive shade.

7. *Artificial Indigo.*—This dye may be said to be historically one of the most interesting of artificial colouring-matters. The artificial production of indigo had long been—in Germany at least—the dream of the tinctorial chemist and the hope of the capitalist at his service. It has been produced at last—praise be to the prince of dauntless chemists whose lot it was to search for and find the treasure—but, alas! at what cost, and with but how small results! The discoverer of the production of indigo by artificial means laboured for twenty years for it, and he and every one in the trade of colour making or using, or in the profession of technical tinctorial chemistry, expected that not only fame but an immense fortune would accrue. Unfortunately, artificial indigo has so serious objections to its use that by most printers it has been altogether discarded.

8. *Alizarine Blue.*—This is perhaps the most important of recent discoveries in tinctorial chemistry. Alizarine blue is now an almost indispensable dye in all our leading calico printing establishments. Alizarine blue is a dark chocolate powder soluble in cold water to a brown solution; on printing this along with acetate of chrome a magnificent indigo

blue is obtained, which is one of the fastest of artificial dyes—in fact, it is as fast as alizarine red.

C. Yellow Artificial Colouring-Matters.

None of the artificial yellow dyes are so fast as berry yellow. The fastest artificial yellowis the newly discovered *auramine*, which although exceedingly fast, and fast enough for most purposes, is yet surpassed in this respect by berries, notwithstanding the fact that auramine is coming into extensive use, and will doubtless take the place of berries to a very large extent. There are a great number of artificial yellows which in brilliance lack nothing, but in fastness lack everything. We shall follow our usual plan, and mention only those yellows which are in general use, and in the use of which the writer has had some experience, both in the large scale and experimentally. The only artificial yellow dye which we deem it necessary to treat of is *auramine*. Auramine was discovered—or first brought into the market—in 1884. It is a yellow powder, readily soluble in water, alcohol and acetic acid. When printed with tannic it yields a fine shade yellow which resists well the action of light soap and dilute acids.

D. Green Artificial Colouring-Matters.

Aniline Greens.—Many distinct varieties of aniline green are manufactured. Those most extensively used in calico printing, and those by which every variety of shade of the greatest stability can be obtained, are known as Methyl Green, Malachite Green, and Crystal Green. The latter is that used in all ordinary prints; it yields a brilliant and exceedingly fast green colour, which has the additional recommendation' of cheapness.

1. *Aniline Crystal Green* (Benzaldehyde Green).—Bitter-almonds-oil Green ($C_{27}H_{34}N_2O + ZnCl_2$). Varieties in trade known by such names as imperial, emerald, brilliant, china crystal, and new crystal green. Some of these are slightly varying qualities or varieties of crystal green, but which do not differ materially in properties. Thus, one variety has the formula $C_{23}H_{26}N_2O + ZnCl_2$, which, except differing slightly in strength from other varieties, is in no wise different in quality from the first-mentioned variety.

Crystal Aniline Green occurs in commerce in the form of beautiful copper-coloured, metallic-looking crystals, varying in average size from that of small pin-heads up to that of millet (?) seeds, according to the method of crystallisation and the composition of the green. These crystals generally solely consist of the pure dye, and dissolve readily and completely in water, alcohol, or acetic acid. Crystal green yields with tannic acid an exceedingly bright and fast green, which is largely used in printing. It may be fixed with alumina, but is then wanting in stability or fastness.

Methyl Green, $C_{23}H_{25}N_3 . 2CH_3Cl$. This is generally supplied in the form of a dark green or olive-coloured powder, which dissolves readily in water. It yields with tannic acid a bright green, of yellower and more delicate shade than that produced by crystal green, and less fast. The shade of green produced by methyl is often preferred to that yielded by crystal green. It may be fastened with alumina or alumina and tannic acid in dyeing, but shades are obtained which are looser than that obtained by tannic acid.

E. Violet Artificial Colouring-Matter.

Aniline Violet, Methyl Violet, Uncrystallised Violet, Mauve.—This beautiful dye is equal in fastness to crystal green, and is in equal request amongst printers and dyers. It is supplied in the trade as a powder, or in lumps, but not in crystals. It dissolves in water, acetic acid, and alcohol; when printed with alumina paste it yields a beautiful and brilliant violet, which is fast to light and soap. It may be employed with tannic acid: a faster, but not so bright a colour, is obtained.

F. Brown Artificial Colouring-Matter.

Bismarck Brown.—This dye produces, with tannic acid, a bright and fast brown, which is largely employed in printing, both singly and in combination with catechu and other colouring-matters.

TESTING OF DYES.

In a work of this nature the subject of testing each individual dye is too extensive to be dealt with; and yet it may be useful to our readers to mention a few general practical methods that will in most cases determine pretty accurately the value of a dye in reference to the use for which it is intended.

In the case of nearly all aniline colours 20 to 40 grains are dissolved in about ten times the weight of acetic acid at 8° Tw., by warming; the solution is cooled and mixed with 1 gill either of alumina paste or tannic paste, according as the dye is to be employed in the one or the other. This colour is strained through fine calico, printed on calico previously prepared with oleine, or unprepared as the case may be, steamed, and either soaped or passed through a tartar emetic bath, and soaped according as alumina or tannic acid paste is employed. The shades obtained are then compared as regards shade and fastness. Modifications, of course, are observed according to circumstances.

Another method is to dye-up equal-sized swatches of cloth, printed with a mordant, and steamed, etc., in weighed quantities of the several samples, in equal quantities of water, in small dye-pans exposed to the same temperature. This method is also applied to alizarine, sumac, logwood, peachwood, berries, bark, tannic acid, etc. In the case of alizarine the fents—pieces of calico—after dyeing are washed and slightly dunged, dried, prepared in oleine, dried, steamed $1\frac{1}{2}$ to $2\frac{1}{2}$ hours, and soaped, washed and dried, and the shades obtained are compared.

THE FARMER AS A TECHNICAL WORKMAN.

His Tools, Implements, Machines and Materials.—The Principles of his Work in its Various Departments.

CHAPTER XII.

In continuation of the subject begun in last paragraph of preceding chapter, we go on to say that we could not continue to draw from our store of ready money in the bank without finding the time come some day when our cheques would be returned with the ominous words "no effects," unless we kept from time to time paying in to the credit of our account. Liebig maintained that we never as farmers nationally paid anything to the account of the credit of the soil—that we were always drawing out. But, as we have said, Liebig overlooked certain modifying influences which tended and still tend to materially change the conditions of the question. What the chief of those are we shall now glance at.

We of course do not know—we can at the best only conjecture—what the amount is which the soil holds of fertilising constituents; but we are certainly justified in assuming that the amount held is practically unlimited. But they are not available *till we get at them,* or more correctly till we enable the plants by their roots and rootlets to get at them, so as to take whatever they require for their full development. We can conceive the cultivable soil—that is, the upper crust of the earth's surface fitted to bear plants—to be made up of a series of layers horizontally superimposed one upon another. The depth to which these layers extend can in the majority of instances be pretty fairly estimated by test holes dug at different parts of a field; but whatever that depth be, we may conceive of all its layers being made up of soil of a pretty uniform quality as regards its constituents. Assuming the depth of each layer to be say six inches—which may be said to be the maximum depth to which ordinary ploughing stirs the soil—the soil composing this layer will have a certain amount of fertilising constituents locked up in it available for the crop which is to be grown upon it. This crop we may assume to be wheat, the soil being best suited for its growth and development. If we continue to take crop after crop from the soil, we by each crop taken off carry away from or deprive the layer of soil of so much of its constituents; and as these are in amount a fixed and definite quantity, we can easily conceive that the time will come when the six-inch layer will be wholly deprived of its fertilising constituents. There is, of course, the layer next in depth still untouched, with all its store of fertilising constituents ready to be availed of by the plants, if only we could get at them. But if in the practical work of ploughing or stirring the soil we only keep moving the first six-inch layer, and so move it that we form as the floor of the layer a hard bottom crust, in proportion to the hardness of this crust we throw an obstacle in the way of the roots and rootlets of the plants growing in the upper layer, which in proportion prevents the roots from descending into the soil of the second layer, in which they would find an abundance of plant food.

Limit of Soil from which Plants can draw for Mineral Constituents.

No matter, therefore, how great may be the actual depth to which the cultivable soil extends, nor how unlimited the amount of fertilising constituents there existing—if by the necessities or faults of our system of working the soil we get no deeper than the first layer of six inches—we have, to all intents and purposes, only the fertilising constituents to be found in that first layer; so that, by continual cropping of it, it would be gradually exhausted or impoverished. Now, Liebig did not deny the existence of a practically unlimited supply of fertilising constituents in the soil; only, seeing that the actual work of cultivation—that is, stirring of the soil so as to form a seed-bed for the plants—was limited to such a shallow depth, and which depth could not be increased, he was quite justified in saying to the farmers, "You have only got a certain and a very limited depth of soil to work in, and can have no more and no less of fertilising constituents than it naturally possesses: if you will persist in perpetually cropping it under a system which constantly takes from but gives nothing back to the soil, the time must come when you will find your soil utterly impoverished. You may say, and I do not deny the truth of the statement, that there is practically no limit to the richness of the soil in fertilisers, but if you cannot get to the layers of soil which carry these, then, practically, I say you are no better off than before: you are in the position of a starving man with abundance of provisions lying before him or within his sight, but not within his reach, as a broad, impassable river lies between him and what would keep him in life."

But the great chemist dealt only with the fact that the system of working the soil universally adopted in his time practically limited the depth of the soil seed-bed, and as a natural result the amount of fertilising constituents available for the plants, to a wretchedly shallow layer, much more frequently four than six inches in depth, and which, moreover, was so worked that the longer the soil was cultivated or stirred, the harder the sole or crust at the bottom, forming the floor of this thin shallow seed-bed, became,—so that just in proportion as the seed-bed got exhausted by continued cropping of its constituents, and as in proportion the plants required a greater supply of these, which could only be found in the layer immediately underneath—so the barrier got firmer

and firmer, more certainly excluding all hope of reaching the treasures of fertilisers in the deeper layers of soil. But he overlooked the fact that there was a possibility of so working the soil as to give to the farmer a *much deeper* seed-bed than he had been accustomed to, and a further possibility of so getting this deeper actual seed-bed that there would be no hard crust or sole intervening between it and the layers of soil below it, and that the roots and rootlets of the plants could find access to the unlimited store of fertilising constituents present in the lower layers. Considering the then condition of the mechanical aids to soil cultivation, Liebig was amply justified in assuming that the system of working it then universally prevalent would be perpetually employed. He evidently decided that this would be precisely so; but we have little doubt that if he had foreseen or, better still, had lived long enough actually to see what is now done every day in deep culture, not merely by the aid of the steam cultivating systems of Fowler or of Howard, but by improved methods of land working by horse power, he would have greatly modified his views as to that ultimate exhaustion of our soils which he feared was very much nearer than he cared to contemplate, and the natural and indeed fearful losses arising from which he described in strong and striking language.

Restoring the Fertilising Constituents of the Soil.—Liebig's Theory.

The system which Liebig advocated as the means of averting those evils was, simply stated, that which gave back or restored to the soil the elements of fertility of which, by the system of cropping, it had been deprived. And the readiest, and, as he maintained, the scientific system of so restoring to the soil its elements of fertility, was that in which the utilisation of town sewage or refuse played the chief part. Liebig's great supporter in this view of the whole subject of exhaustion of the soil, and of the system by which its evils could be averted, was the late well-known agriculturist Mr. Alderman Mechi, who up to the day of his death was a most earnest and zealous and able exponent of Liebig's views.

But there was another modifying influence, which the great German chemist generally overlooked—indeed, to some extent wholly ignored the existence of. He seemed always to write on the subject of land exhaustion as if farmers—and especially British farmers, upon whose evil doings he rarely if ever seemed tired of descanting—were engaged in all their cropping in perpetually taking from the land and never giving back to it its fertilising constituents. It always seemed to us a strange thing, to put the matter in its mildest form, for Liebig to assume this, when he must have known that our farmers at least, whatever Continental agriculturists might do, spent large sums in the creation and the purchase of manurial substances, which they were continually applying to the land, and thus restoring to it at least a large proportion, if not giving back the whole of the fertilising constituents which had been taken from it by a succession of crops. It always seemed to us, however, that Liebig was so wedded to his town refuse or sewage system as the only one calculated to keep up the fertility of our soils, that he came to look upon other manures, such as farmyard manure or dung of animals—notably for years, and as it is indeed still, the manurial mainstay of the farmer—as matter of but little account.

But this supreme advocacy of the system of giving back to the land in the shape of the refuse of our towns those fertilising constituents of which the populations of the towns had deprived it by consuming the crops or produce, was reserved for a later period in the brilliant career of Liebig. For at an earlier period he applied his own peculiar views as to the science of manuring, or rather that of maintaining the fertility of the soil, to the devising and through the aid of others the manufacturing of certain manures which he advocated as the best to be used under what he maintained to be the peculiar and the practical circumstances of farm cropping. To these manures were given the name of "special" or "specific" manures, based on the theory that as each plant took from the soil its own peculiar set, so to call it, of fertilising constituents, the true system of manuring was to have a manure or fertiliser *specially* adapted to the special crop. Such was the high estimation in which the abilities of the great German chemist were held in this country, that our farmers were at once so attracted to this new system of special manuring, that they gave great and wide attention to its development in their actual farm practice. There was such a scientific precision in the theory of Liebig, and, moreover, such an appeal to what appeared to be after all the common-sense view of the system, that it exercised almost immediately on its promulgation a wonderful fascination on the whole body of farmers in this country, especially of those advanced in their ideas, who laid some claim to be men of science as well as of practice. Unfortunately for Liebig's fame, and assuredly for his after influence with British farmers, the extensive adoption of his system of special manuring led, and that very quickly, to its equally extensive failure. And, considering the completeness of this, it should not be a matter of surprise that when Liebig pushed forward his later views on the exhaustion of land, and so strongly advocated the town refuse system as the only mode of averting its evils, the British farmers turned a deaf ear to his protestations as to its extreme value. That there is a vast deal of truth in the statements

of those who advocate the use of town sewage, the general form of town refuse, no one is disposed to deny; but those who have thoroughly investigated the subject are none the less prepared to assert that there are circumstances connected with the town sewage system which tend greatly to modify its manurial value. On this subject the reader may find some remarks elsewhere in this work, if space permit of their being given.

Objections held to Liebig's Theory of Restoring Constituents to the Soil.

But the scientific views or theories held by Liebig on the whole subject of land fertilising and manuring were not allowed to pass unchallenged. The great exponent of what may be called the per-contra side of the important question were Messrs. Lawes and Gilbert. Through a long series of years these gentlemen, versed profoundly as they were in chemistry, as well as possessed of a sound knowledge of practical farming, carried out a most extensive and elaborate series of experiments on a large and effective scale. But they also, through the medium of a most elaborate series of papers published in the *Journal of the Royal Agricultural Society of England*, gave the results of those experiments, investigations, and researches to the British farming public. So ably were the views of those eminent *savants* expounded, and so corroborated by the results of experiment and of extended practice, that their cultural creed, as it might be called, became and is now the creed of the British farmer on all points connected with the cropping of land. What that creed is we shall see at a future stage of the present series of papers. We are concerned here chiefly to show that by the new system of the mechanical working of our soils a new era of cultivation is opened up, and the difficulties connected with their exhaustion greatly lessened, if, indeed, they are not to a great extent wholly overcome. We have already in the earlier chapters dwelt somewhat fully upon the advantages derivable from the deep culture of our soils, in which, as now is generally acknowledged, lies the secret of not only maintaining but increasing the future fertility of our soils. On some of the practical points of deep land culture we shall have yet something further to say.

Exhaustion of Soils.—Practical Points connected with it.

But before discussing this most interesting department, the exhaustion of our soils, it will be well here to note some practical points still further affecting it, and greatly modifying the views of those who still fear that the views of Liebig are the truest ones (and there are many who still do so), and that we shall yet have nationally to regret that we have recklessly gone on deteriorating the fertility of our soils, reaching at last a point where their impoverishment would be simply a national calamity. To such the following assumption may be of some comfort. It is based upon a pretty accurate estimate of what we really know, and maintains from this, which is as likely to hold good for the future as it has been true for the past, that our soils contain a much greater amount of fertilising constituents naturally than even the most sanguine believed at one time, when less was known absolutely than we know now. This assumption is based, as we have said, on a number of general facts obtained in long practice, and from which it would be scarcely wise to deduce truths specially bearing on its truth. But we have some special experiences which are almost positive proofs of this. Thus we have the experience of many years obtained by carrying out the Lois Weedon system of cropping land. On this system a piece of land was kept under cultivation of the *same crop*—that is, a continual succession of crops was taken from it—for the long space of fifteen years. During that time there was taken from each acre of land about three and a half times as much phosphoric acid, about seven times as much potass, and about thirty-seven times as much silica, as would have been taken out of the soil under the ordinary course of cropping. Yet, notwithstanding this extraordinary drain upon the supply—the natural supply—of fertilising constituents in the soil, its fertility had in no wise diminished, it being at the end of the period as capable of bearing good crops as it showed itself at any period of the long term. The able and well-known agricultural chemists, Messrs. Lawes and Gilbert, give us also a very decided result of their investigations bearing upon this point of exhaustion of the soil. These investigations had reference to no fewer than forty-two analyses of fourteen different soils, representative of the various soils of the kingdom. And the result of carefully elaborated experiments with those soils showed that if they were cultivated on the ordinary system of *rotation of crops*, using farm-yard or home-made manures, and selling off only corn and live stock; and supposing the soil were cultivated to the depth of one foot—a depth, be it observed, far exceeding that in ordinary use, in most cases not six, and in many cases only four inches deep—the following would be the result:—To exhaust the twelve-inch depth or layer of soil under the above treatment, it would take one thousand years to exhaust as much phosphoric acid, about two thousand to exhaust as much potass, and about six thousand as much silica, as experiment showed to be present in the average of the fourteen varieties of soil experimented upon.

Facts such as these would certainly seem to indicate that the fears held by some as to the exhaustion of our soils to that point at which they would cease to bear productive and paying crops are somewhat lacking in common prudence, as they appear to be baseless as regards scientific facts. And the case in

favour of the view that such fears are groundless is all the stronger when we bear in mind that we have now, with our improved mechanical means of stirring the soil, a depth far in excess of that which our best means years ago enabled us to obtain, and thus have the means of increasing to a practically indefinite extent the layers of soil which, as we have seen, have a supply of fertilising constituents that is practically inexhaustible. When we state generally that by the systems of steam cultivation now in daily and extended use we can obtain a depth of stirred soil practically equal to two feet, we have little reason to fear that our soils will be exhausted to the calamitous extent which some seem still to think not only a possible but a very probable result of our system of farming. Still less reason to fear when we can restore, as we do practically restore in many cases, by judicious manuring and special methods of cultivation, the fertilising constituents we take from the soils through the medium of the crops grown upon them.

We have been thus particular in making clear to the reader the various points connected with the exhaustion of our soils, not merely because the question has a direct and practical bearing upon a point of the greatest importance to us as a people, with all of whom the art of agriculture is one of vital interest, but because the points involved have also a direct reference to the subject of soils generally, upon which much has yet to be said.

Rotation of Crops.

In the last paragraph but two in the preceding chapter the reader will notice the phrase "rotation of crops." What is meant by this and the important practical points in farming which it involves we now propose to describe. The subject of "rotation of crops" is so called from the fact that different crops are alternated on the same soil in sets or series, so that in the course of years any one crop in the set or series comes round so as to be repeated. It is closely connected with the subject of exhaustion of soils, and is based upon the same theory—namely, that as each crop takes from the land its own peculiar class of fertilising constituents, a continual succession of the same crop on the same land would, as a natural result, deprive the soil of that particular class of constituents, leaving those others in it which the plant did not require. There would thus be, as a final result, a soil in which there would be a deficiency of some constituents, while there would be an excess of others. Thus, a silica plant continually grown upon the same soil would be continually depriving it of the silicious constituents, while a lime plant would in the same way be carrying off the lime, leaving other constituents which they did not require. The same principle applies to the relation which exists between crops and the manures with which the soil is artificially supplied. Thus, farm-yard manure or dung, or muck, as it was universally called in the old times—an old Saxon term, somewhat unsavoury in its sound and association, but admirably graphic or suggestive to the popular mind—contains all the elements of fertility, arising from the fact that it is almost universally composed of the excreta of farm live stock, or animals fed upon food much of which is derived from the very crops grown upon the land of the same farm, such as beans, corn (oats), and the wide variety of green and forage crops, such as turnips, mangolds, grass, clover, and hay. Now, as through the medium of farm-yard manure—the more euphonious, if less terse and brief, term by which the old material muck is now almost universally distinguished—all the fertilising constituents of plants are given to the land to which it is applied, it is obvious that a constant succession of the same crop on the same land would have the result as above stated with reference to the crop and the fertilisers present in the soil *per se*. Farm-yard manure, continually and regularly applied to it, would keep up the fertilising quality of the land, and this for a continuity of time; but if only one crop were taken off the land thus manured, taking off with it only its own peculiar class of fertilisers, there would of necessity be an excess of some other fertiliser accumulated in the soil.

Whether, therefore, considered in relation to the soil as a source of fertilisers for the crops, or in relation to tho e supplied artificially to it through the agency of continued and regular supplies of farm-yard manure, the crops of the farm are so arranged, in the succession in which they are taken from the soil, that the fertilisers not taken up by one crop, and therefore left in the soil, shall be taken up by the crop which follows next in succession. From this a little consideration will show that there are two elements in the case—first the soil, and second the manure, as each the special source of plant or crop fertilisers; and that as a practical deduction from this and the peculiarities of plants as continual carriers away of these fertilisers, the exact nature of the rotation or succession of crops will be regulated by the natural condition of the soil, as well as by the requirements of the plants grown upon it. Rotations, therefore, practically vary according to circumstances. But there is still another element in the question of "rotation" which must be considered.

Classification of Farm Crops.

Farm crops may, in a general way, be divided into two great classes or families—"grain crops" and "green crops," each of which has its sub-classes or varieties. What these are, and what the peculiarities of their cultivation, will be fully detailed in future chapters in the present series of papers, if space permit.

THE FACTORY OR MILL HAND AS A TECHNICAL WORKER.

THE ORGANISATION, GENERAL DUTIES, AND SPECIAL WORK OF THE STAFF OF FACTORIES FOR THE PRODUCTION OF SPUN AND WOVEN GOODS—THAT IS, "YARN" AND "CLOTH"—AND THOSE CHIEFLY IN COTTON AND WOOL.—GENERAL DESCRIPTION OF THE VARIOUS PROCESSES OF MANUFACTURE.

CHAPTER XVII.

REFERRING to our description of the different kinds of yarn, begun in last paragraph of preceding chapter, we have to note that the fine yarns (one hundred hanks to the pound and upwards) are invariably made into twofold yarns for manufacturing laces, alpacas and other similar kinds of woven goods. Twofold, threefold, sixfold, and ninefold cords, are made on the doubling frame. Sewing threads, of whatever the number of cords or strands, are made on this frame.

"Fold" is understood in the "trade" to mean soft or medium twist, but "cord" is known or understood as yarn, it having much twist in it, and of course it is stronger than fold, though the same number of ends are in each. The fold is used for soft manufactured goods, but the hard twisted or cord is used for manufactured goods of a harder, stronger texture. The difference in the number of twists per inch gives to the article when manufactured a feeling altogether different from that of the soft twist. This often accounts for the different appearance, as well as for the change in the handling.

In thread making, "three cord" means three ends run together and hard twisted. "Six-cord" is made by doubling two single ends into one thread, and hard twisting, then three of them twisted into one thread. "Nine-cord" is made by twisting three single ends into one thread, twisted as above; then the three threads as before twisted (called "preparing") are again twisted together (a second doubling), and thus nine-cord thread is manufactured. All kinds of yarn, other than single yarn, are made in a similar manner, such as knitting cotton, worsted yarn, angola, etc., etc. It would be useless to continue a description of this doubling or twisting machine, as we have given a full one of the throstle. The difference is principally in the roller part, it only having two rollers—*i.e.* one above the other, the bottom roller being driven by tooth and pinion, ("positively" driven,) the top roller being driven by friction from its weight on the bottom roller, this being sufficient to draw the thread from the cop. Cop doubling (*i.e.* doubling from cops) is most in use for the fine counts of yarn. In doubling the coarse or coarser counts of yarn, the winding of the thread from the cop upon a bobbin is generally adopted, and such a doubling frame is termed a "bobbin doubling frame"; when yarn is doubled from cops as they come from the mule the frame is called a "cop doubling frame."

The doubling frame is more simple from having, as is termed, one line of rollers only, whereas the throstle has three lines. It will be evident to the reader, in the case of the throstle, that more gearing is required to drive the three sets of

rollers has to move at a different speed from the other, while in the "doubling frame" only one line has to be driven and therefore the gearing is very simple. The doubling frame has a "traverse" motion precisely like that of the throstle frame, to regulate the even motion of winding the thread upon the bobbin, so that the bobbin can be equally filled from top to bottom. The full bobbins, as taken from the frame (if coarse counts) are taken direct to the reel, which has been mentioned before.

Clearing Frame for Yarn.

Fine counts are generally required to be freed from thick ends and lumps, and therefore the thread has to be operated upon by another machine, which is called a "clearing frame." The name is certainly a very appropriate one, as the object of it is to free the yarn from lumps or other matters which would otherwise give an appearance of a common quality of material. This process is only in use where good qualities of yarn are desired. The arrangement of the frame is much like that of the cop-winding frame we have just described, excepting in the rewinding of the thread from one bobbin to another. Between the two bobbins there is a plate or plates, called "clearers," which can be regulated,—*i.e.* the slot, notch, or opening can be made wider or narrower, so as to be arranged for finer or coarser counts of yarn. The yarn, as it leaves the bobbin which has been brought from the doubling frame, passes through this notch, and any thick ends or lumps are either drawn off or broken, not being allowed to pass the "clearer." The tenter called a clearer makes good the broken part by tying the two ends together, and thus the yarn passes on to another bobbin. This yarn, being so cleared, is most used for lace-making purposes, or for a good class of alpacas or other similar goods, and thus the manufactured piece presents a more even and smooth surface. If it is intended to be sent off in the bundle form for bleaching or dyeing, it is then reeled as we have before defined. If it is then to be used for warp purposes, it is put in the form required for the longitudinal part of a piece of cloth. Doubled yarn is mostly used for lace, or otherwise used in the manufactured goods of the Bradford class, cotton warp and worsted weft.

Warping.

The warping mill is also one of those machines which is of very simple construction. It has what

is called a "creel." This creel contains two to three hundred bobbins, which are all full of yarn. The next part of the machine is called a "heck." This heck is provided with a series of small eyes made of steel, for the thread to be guided in a certain form, so that regularity may be obtained in passing through the whole of the threads round a pulley, which then forms what is called a "tape." All the ends (sometimes three hundred in number) are drawn into this tape form, and are thus wound round what is called the "mill." This circular mill is made of timber, composed of staves set twelve inches apart and about seven feet in length, which are held in their position by three inner circles, one at the top, one in the middle, and one at the bottom of the staves. Mills, according to their requirements, vary in their circumference—say from ten yards to eighteen yards. The tape is then drawn round these staves by the motion of the mill going round, and a spiral motion is given, which causes the tape to wind round the mill in the form of a screw, and when it arrives at the top or bottom it can easily be reversed and thus go back again, and then the tape is laid upon that which was first put in the mill. If it has three hundred ends in the tape, by going up and down six hundred ends will then be in the tape; this can be as often repeated as is necessary to produce the number of ends required in the tape. It is then folded into a ball. Being in this condition it is well calculated for dyeing purposes.

Where the yarn is intended to be used in the grey state (*i.e.* in its natural colour) it is mostly warped on a beam, instead of the mill, and it is thus ready to be taken to the sizing frame. All yarns which are sized have to run upon a beam, and then a series of beams are placed so as to have the number of ends (threads) upon the finishing beam that are requisite for the breadth of the piece for which it is intended.

Weaving.

In preceding chapters we have explained the various processes through which the cotton fibre passes in being changed into the condition known to the trade as "yarn," the general characteristic of which is perhaps more clearly understood by the popular name of thread. We have now arrived at that stage of the general process of "cloth," or, as it is technically termed, "calico" making or manufacture, in which the yarn is formed into a fabric of greater or less fineness; this fineness being dependent upon that of the yarn, and the number of threads which go to or are comprised within an inch of the breadth of the cloth or piece of calico. The number of yards in the length of the cloth made, and which, as a whole, constitute what in the trade is called a "piece" of calico, varies according to circumstances. The process by which yarn or thread is formed into a certain fabric or cloth is that known to every one as "weaving"; the machine used being known as a "loom."

The progress of the industrial arts is attended with great changes, as to the mode adopted and the means of carrying it out. Such changes affect the supply of the necessaries and luxuries of life. All changes in our productive industries tend in one direction—that of producing articles of general use with less manual labour—and thus mankind is relieved from drudgery. Man's labour has now become more of a superintendence of machinery for producing articles of use than of manipulating the articles himself. To run back fifty years ago, or little more, when nothing but hand-loom weaving was known, we see a mighty change in it. The labour now in attending the working of three looms driven by machinery is much more profitable for the labourer than that of working one loom by hand, as in the old system. The labour of the present system is much more in favour of the attendant than that of the former.

The money made or wages earned on the present plan of machine or "power" weaving is also more favourable to the operative than the old system of cloth weaving, and the cloth is produced at a minimum cost, which is also a great consideration to the public. It would perhaps be useless to go back as far as the memory of the oldest man can reach in describing the various methods adopted to produce the most satisfactory result in weaving. Some notes will be given in due course. The improvement in the mode of producing cloth is so far ahead of what can be remembered by many of us, that to the present generation of weavers the old system could scarcely be credited with the work it actually did. It must be understood that as "Rome was not built in a day," so the changes in manufacturing cloth which have taken place during this century chiefly, and going back a little in the last, were introduced slowly. And those improvements which may be described as recent have only resulted in bringing about changes of a minor kind. But like the number of pence in making pounds, the number of changes in the working parts have made the present "power loom" a comparatively complete machine. If we were to say that the number of patents which have been secured for improvements in the loom are best described by the word "legion," we should only give the idea that hundreds of them have been obtained for purposes of improving it in its working, with the view of producing more yards of cloth in the same time, and in other ways that the cloth should be more saleable—*i.e.* freer from faults. Both objects have been gained, and thus this wonderful machine called a "power loom" or "steam loom" is now in a complete state. We dare not venture to say that it

is perfect, though those unacquainted with such a machine, seeing how regularly every motion in it (and there are not a few) works with such precision and with a continuance of the same throughout the day, week, or year, might be excused if they expressed the opinion that perfection in the power loom had at last been obtained. At the time that the power loom was introduced it was condemned on all hands, on the grounds, first, that it never could make a piece of cloth equal to that made on hand looms, and, in the next place, if it did succeed, the labour would be taken out of the hands of the hand-loom weavers, and this would cause all the hand-loom weavers to be thrown on the parish for relief. Many of the hand-loom weavers, instead of believing in either starving or in applying to the parish for support, at once turned to the power loom. However, all such changes must to some extent cause many to be thrown out of employment for a time. Improvements in preparing or making materials of any kind have always been appreciated by some, and with others regarded as robbers of labour and producers of poverty and misery. Such ideas as the latter are now obsolete—dead. The opposite to the above opinion has been proved so often, that all machinery introduced to save manual labour is welcomed by the thoughtful of the community, as a direct gift of great value to it.

Three kinds of labour are recognised as necessary to bring all the fabrics of weaving successfully under the head of machinery:—First, the common power loom for the fabrics to which it is at present applied, and which will be explained presently; secondly, the vertical loom, for the coarsest textures or cloths, made of the most hard and rigid fibres; and thirdly, the spring loom, adapted for the production of the finest and most elastic fibres, such as muslins, etc.

Plain weaving consists in the interlacing together of two lines of thread lying at right angles to each other. The long threads running from end to end of the piece are called "warp." The cross threads, which run from side to side, or selvage to selvage, are called the "weft." The simplest explanation we can give, so as to be understood by those who have not seen the operation of weaving carried on, is by drawing their attention to the system of darning a stocking, *i.e.* by moving every other thread, and that being done alternately the piece is much alike on both sides of it. This alternate threading of threads with the cross threads is "weft." The cloth when finished is firm, and in no case are any of the threads left loose. This alternate threading of the weft with the warp is performed in a very simple but certain form. The way in which it is accomplished is precisely like that of the hand loom. In very early times this plan of raising every other thread of the warp was introduced, and the same plan is adopted to-day, but in a more mechanical way, which produces the same result. It is most remarkable that the first or original principle of working which has been adopted, whether in the preparation for spinning, or in spinning of cotton, or in short of weaving, has been and is still maintained. There are changes, no doubt, in forms adopted, which produce a larger quantity, and also a much more perfect result, but the original principle remains. The object and therefore the aim of every ingenious man is to improve on that which is already in use. Though the form of the machine may have been altered when something has been added to or something taken from it, in the principle of it no change is perceived. In spinning, and in preparing for spinning, drawing and twisting are now performed as in former times. So it is that the same process of threading of the weft alternately in weaving with the warp is carried on. We shall not at present refer to the old system of threading the weft into the warp with a needle, more than saying that such was the case; but what we have more to deal with is, as we have done through this paper on cottons, that which is in use generally at the present time.

Parts and Operations of the Loom.

We now take up the various parts of the loom; and first as to the "shuttle." This may be compared to the form of a long narrow boat. In one end of it is a skewer, or tongue. On this tongue the cop called a "shuttle cop" is passed (skewered), and at one end of the shuttle is a small hole through which the end or thread from the cop is drawn. This shuttle is so arranged that when it is at one side of the piece it lies in a box. This box is supplied with what is called a "picker," made of leather. This picker gives a jerk, or a smart push, which drives it across the piece, and there it lands into a similar box, and is thus treated as it was at the other side. This kind of shooting backwards and forwards of the shuttle is continued so long as there is any weft left in the shuttle, unless by some misfortune this (the weft thread) breaks, the loom in this case being stopped until the same is repaired by the attendant. When the weft in the shuttle breaks, from whatever cause, the loom stops instantly by its own mechanism. There was a time when this breakage of the weft was a drawback on power-loom weaving. In course of time an invention was brought out which is known by the name of "weft fork." When the thread breaks, the weft fork changes its position, and so operates on the rod which is attached to the strap fork, and thus causes the loom to stop; there is thus no damage done to the cloth. When the weft is made good the loom can be set to work without turning any part back. It would be useless if the weft passed forward and backward, unless it could at the same time pass in such a way as to "darn the warp," so

to say—that is, go in and out of the warp yarns. The warp, being the longitudinal part of the piece, is so fixed that the position of the threads is in the like form throughout the whole length, and therefore the threads are raised in turn—*i.e.*, every other thread in the warp is raised as the shuttle passes from right to left. Then, when the shuttle moves from left to right, those threads which were so operated upon as to fall to their former place, and those which were holding the lower position, are raised in time for the shuttle to pass through.

This process of raising and depressing the threads alternately also continues with the same regularity as the to-and-fro movement of the shuttle. This opening of the threads alternately is produced by what is commonly called a "treddle." This treddle is attached to what are called "heddles," or "healds." The healds being made of thick threads called "heald yarn," are fixed to rods at the top and bottom, and in the centre of this thread an eye is inserted, through which the threads of the warp are put. Having two of these healds, every other thread is put through one length of the healds, and in the other heald is put the other half of the threads which were left. The rising of one of the healds raises half of the threads, and keeps them in position until the shuttle has been shot through the division of the threads, and then the healds being reversed the shuttle returns. This repetition of the shuttle and healds produces that even cloth which is to be seen in plain calico. It is almost impossible for any irregularity in the cloth to appear when the loom is in a proper condition, because the healds having the threads are so correctly arranged, alternately rising and falling, and the shuttle passes to and fro with such mathematical precision. When the weft passes through the "shed" (opening of the threads by the healds), each time that the shuttle is shot the weft in the shuttle is held by the outer thread of the piece. In short, the thread is passed half way round the outmost thread of the warp, and this forms what is termed, and is known by almost all, as the "selvage," or "selvedge." It will strike the thoughtful reader that something more is needed to make the cloth firm. Weaving as carried on by this almost universal method consists in the performance of three motions in succession; and these are, first, the shedding of the web for the introduction of the shuttle with the weft shot; second, the throwing of the shuttle through the shed; third, the striking home of the shot. We have described the two first processes in weaving; we now speak of the "third." The "striking home" is performed by what is termed the "lathe." The frame called the lathe is so fixed on a high part of the loom, and is suspended from its place, and can thus be oscillated perpendicularly between the fell or verge of the cloth and the heddles like a pendulum. This lathe is so made that a reed can be inserted between the frame of about four inches in breadth, and through this reed the threads of the warp are drawn. The threads are thus separated, and the lathe, frame, or reed so constructed as to allow the threads to rise and fall with the movement of the heddles or healds. The object of the "lathe" is to press the last thread of the weft close up in the piece against the thread crossed previously; the movement of the lathe being so mechanically constructed that each strike or blow upon the thread as it is delivered by the shuttle gives a certain pressure, and thus evenness of cloth is produced. This is more certain than that which has to depend upon the action of the human hand. The force of the lathe blow must likewise be varied according to the work and the speed at which the loom is driven. Its momentum must be sufficient to overcome the reaction of the weft shot; and as this reaction varies exceedingly in the different makes of heavy calicoes, the loom is much limited on that account in its application to different fabrics.

The various movements we have described must work in perfect unison with each other. Should one action be either too soon or too late, the whole of the motions might as well be out of order. In the early days of the power loom springs formed a very powerful element in the movements of the loom. Those acquainted with machinery find that spring motions are not the most trustworthy arrangements in a machine for certainty of action. They are at times, under certain circumstances, very useful, and it seems as though nothing could be used in that place or position to act so well. The use of a spring, as long as it can be depended upon, may be retained. To dispense with a spring often requires a multiplication of wheels or levers to compensate for the change. At a comparatively early date of the power-loom inventions the springs were very much dispensed with by a Mr. William Horrocks, of Stockport, the true inventor of the practical power loom, that which with various modifications and improvements is working at the present day.

Another very important movement in the self-acting or power loom was required—namely, a continual "let off" of yarn from the beam which contained the warp. This could only be done by mechanism very finely arranged. A beam when full of yarn (warp) may be fourteen inches in diameter, but every revolution of it lessens the diameter. This then acquires a continual change of speed, and this speed must be equal to the beam which draws on the finished cloth. It will thus be seen how accurate each part of the working mechanism of a steam-power-driven self-acting loom must be in order to insure certainty of working action.

THE WORKMAN AS A TECHNICAL STUDENT.

How to Study and What to Study.

CHAPTER XVII.

Method in Study (*continued*).—**Arithmetic.**

In studying arithmetic, as in the higher developments of its principles it may be said to involve the study of mathematics, the reader will thus see that he must carefully master its details; becoming thoroughly acquainted with the principle of each rule, not merely "doing" after some fashion or other—and this in too many cases will be but too pernicious in its results on the mind of the pupil—the "examples" illustrating the "rule," or such sums as his teacher may set him, supposing him to be other than self-taught. And, as each rule is thus thoroughly mastered, not "learned off by heart" but intellectually understood, he will find in the knowledge gained a power or strength which will help him all the more easily to master the next rule succeeding; and thus, by a series of steps, he will become a master in the science of figures. And he will, long ere he has reached this point, have learned also this lesson,—that each step or link is connected with another, and unless all are taken up in due course success in the true sense of the term cannot be secured. And as the science is made up of a series of steps, so is each step dependent for its inherent value upon a variety of details. Those can be no more missed out, if success be desired—and this is what, at the least, each one wishes—than can any one step or link in its entirety. The overlooking of one detail, however indifferent in value because minute it may appear, is precisely the reason why calculations become incorrect. And to avoid such mishaps requires the closest care on the part of the pupil. And it is a matter of painful fact that such neglect or overlooking of what are called the minor details of calculations occurs much more frequently than many are disposed to admit,—and this even amongst those who, engaged in the actual work of life, can scarcely be classed as pupils or learners. Even the most careful is constrained to admit that at times, through sheer carelessness, some figure has been altogether left out, put down wrongly (as a 7 for a 2, or the like), that is, some other figure substituted or its position in the sum misplaced, as a sum of shillings figuring as pounds. And such carelessness we are also constrained to confess has, at times, when perpetrated, led not merely to some grave miscalculation leading to loss, but to mental distraction and anxiety, as giving the impression that matters were worse than they really were; or, what is perhaps worse, leading to a false security in the notion that affairs were better than they actually were.

Now, by the pupil beginning from the very outset with a determination to make mistakes, so to say, impossible, by a most rigid carefulness, he will find that in process of time the mental faculties engaged in the work of calculation will become so strengthened that he will, as it were, intuitively carry them out with absolute accuracy. But this position, which is alone that which is worth obtaining—for less than this is equivalent to loss—can only be secured by the pupil being determined not to aim at speedily grasping the subject of study, as a whole, but by patient work and "dogged resolution" to be sure of success in one step before proceeding to take another. It is thus that in time he will become a trained and expert calculator; and this, if it means anything, means that he is as accurate as he is apparently quick. The ancient Romans had a proverb which, freely translated, means that celerity or quickness in any undertaking is gained by being slow,—that is, in other words, to be sure of the ground you are wishing to tread, and this can only be done by patient and careful trial of each part, a hasty advance being likely to end in one's being plunged into a quagmire whence further progress is simply impossible.

The proverb and the lesson it teaches are, so to say, paraphrased in the one current in our own country, "Slow and steady wins the day"; and a further and a graphic illustration of it the youthful reader will remember is to be found in the fable of the "tortoise and the hare." And this further conveys the lesson, pregnant with wisdom to students, that it is dangerous to rely upon mastering a task quickly merely through the force of one's inherent or supposed cleverness or ability, forgetting that all true work is done by patient and generally slow and fatiguing labour. The hare thought he could win the race, as indeed he could have done, in a twinkling; but trusting to his ability to do it in a "trice," and that he could overtake the slow creeping tortoise even when she was within a trifling distance, lay down to sleep, and awoke only just in time to find that the last of the painfully slow crawling steps of the tortoise put her even with the goal. The fable is but too closely applicable to some pupils. It were well if they would lay its lesson to heart.

We have said that the arithmetician and mathematician, trained in the way, slow but sure, we have counselled as the way the pupil should train himself, becomes in process of time so expert a calculator, that all the details upon which accuracy alone depends come before him intuitively, as it were.

The trained mathematician or the arithmetician never dreams that he has omitted any part of the calculation; that in truth part of it consists in attending to everything, so that any mistake, such as we have alluded to, cannot happen. This is a somewhat paradoxical way of putting the point; but, simple as it is, it gives the key to the solution

of the difficulty. It is only when some result is either more striking than he contemplated, or seems to involve something of consequence, that the trained mathematician thinks of doubting the accuracy of his calculations, and admits the possibility that he may have left out some essential factor. But this high point of efficiency is never reached—cannot, indeed, be so—if "rules" and "examples" are treated in the slipshod, careless way some treat them. Work of this kind might as well be left undone, for it is worthless, and the student has but laboured in vain.

What is essential is that the principles on which the rules are founded be thoroughly understood. If this be the case, no words forming a rule are required, even indeed thought of, by the student. The abstract principle which constitutes the rule is to the student a patent fact, so to say, which he carries with him to be ready when required. The essential character, for a thorough knowledge of arithmetic, of the habit of thinking in figures has been already enforced, and it cannot be too frequently borne in mind by the student. For some branches of technical work—such, for example, as mechanics and engineering—are unlike many of those branches of industry in which arithmetic is useful. They differ in this respect: that, unlike them, those branches of technical knowledge have no—at all events few—embodiments of arithmetical facts in which the result of laborious calculations are given in a few lines, easily referred to, and easily applied. Of this kind of information what are called "ready reckoners" may be taken as an example. Tables there are, no doubt, at the command of the technical constructionist; but they are designed chiefly to save much labour in calculation —not to be used by those who do not know the methods by which the tabulated results are found. The engineer, or machinist, while to save time availing himself of those helps in the form of various tables, could, if he so willed, dispense with them, because he would know how to make the calculations for himself. This is essential in certain branches of technical work, for those who follow them have no complete "ready reckoners," which are useful as the ready reckoners of the shopkeeper or the wage-payer, and which are useful alike to the learned and the ignorant in the science of calculation. The work is so varied in character which such technical workers are called upon to design and execute, and its details so numerous, that each is to be, or ought to be, calculated for and by itself, and by its own particular rule. They may thus be said to live in an atmosphere of continual calculation. Nor should it be forgotten, as it too often is, that, in order to be successful in the true sense of the term, they must be also, to a large extent, commercial men,—in so far, at least, as to be able to compass the ordinary work of what is called trade and commerce. This necessitates a knowledge of book-keeping; and this in many branches of technical work, such as that of the machinist, involves many more details than it does in the ordinary acceptation of the term. For it includes the making and keeping of a set of books involving all the details of work done. And as this is so varied, and in one sense so complicated, some idea may be formed of the necessarily elaborate system of "books" required. And the more thoroughly grounded in arithmetic the young machinist, for example, is, the more likely is he to be able to devise and keep a system by which this complicated character of his work may be rendered easily understood. For it need not here be said that even in the case of those branches of technical business concerned with construction of a kind or class more or less elaborate, what is called a business or trade knowledge is required. The trained engineer, machinist, carpenter, builder, etc., etc., should be able to conduct his business so that it will be economically carried on, giving the maximum paying results with the minimum outlay of time and of materials; to which end all those branches of what are called economical or trade education should be so far mastered by him as that he shall be able to ascertain with precision and facility "how he stands," as the business phrase has it,—what his work in every or in any branch of it costs him in time (that being expressed in wages paid) and materials (including in this the amount with which the work is to be debited for plant used, and its wear-and-tear, and all other items of maintenance or outlay). In other words, he should be so much of an ordinary business or commercial man that he will be able always to know with accuracy what his work costs him, and what, therefore, is the profit he makes out of it. But in all this, as in other branches of calculation, the value of the system of mental training such as we have insisted upon as essential to the future success in life of the workman as a technical student will be most clearly established. Such remarks as we have made in reference to knowing the principles of arithmetic apply to mathematics, which, as we have said, is in one sense a higher development of arithmetic, and is, at all events, the basis of one of its calculations. Of course this is only true in a special or reserved sense, as there is much of the work of mathematics which is simply done by the aid of pure reasoning, in which the aid of calculation—arithmetical in its principle—in the ordinary sense of the term is not required.

The Study of Physics.—The Characteristics of Material Bodies and Substances.

We now come to one of the most important departments of technical study—that of physics, as it is

scientifically and technically called—but which, perhaps, is more readily and popularly understood as the study of the characteristics and properties of physical objects or material bodies. While the principles of pure or theoretical mathematics are learned and proved by reasoning, or the exercise of the mental faculties, what is to be learned in connection with material bodies, whether those be in the form of air or gases, liquids or solids, is learned by observation. Reasoning has to do with abstract principles, observation in physical or natural science or the technics of bodies has to deal with facts as they lie ready to be found out and made our own by observation and patient research. And from the facts which Nature is ever ready to show us if we only look for them, and which have been by such a host of patient observers through generations and generations, for many centuries, carefully recorded, there have been deduced a series of "laws," which make up what we now call the science of physics. Those laws have been, and are still, whenever discovered, obtained by a process of inductive reasoning based upon facts. And this grand principle was first propounded, at least, placed upon a sound and irresistibly cogent basis, by the celebrated Bacon, the Chancellor of Queen Elizabeth's reign. And so indissolubly connected with the subject is his name, that the terms, the system or principle of "inductive reasoning," and the "Baconian method," are taken to be synonyms.

To this principle of inductive reasoning, or to the Baconian method, we owe all the discoveries and the marvellous development of material or physical work of every kind which characterises our modern science. Our modern sciences, such as those of mechanics, the steam engine, electricity, chemistry, are all the outcome of laws based upon facts, the innumerable list of which has been collected through ages by a host of patient and careful observers. And this Baconian method, by which from the facts the laws have been deduced, affords us at all times a true test as to whether what is brought forward as a science or a scientific train of reasoning be deserving truly of the name of science, or the appellation of scientific. For if to the question 'Does this so-called science deal with, and is it based upon facts?' the reply 'Yes' can be given, then the term scientific is rightly earned by it. For true science deals with and admits of no conjectures, makes no assumptions, states nothing which cannot be proved by a reference to facts which exist and which cannot be disputed. Hence it is that many discoveries and theories so called by their exponents are mere fancies, as they are founded upon beggings of the question, conjectures and assumed facts, which are not facts, or cannot be proved to be such. The final, the only court of appeal of true science, is that of facts as they are known to exist. It would obviously never do if this were otherwise. For if I am entitled to call to the aid of my so-called scientific exposition conjectures of what may or might exist, assumption that certain things have taken place in the past or will take place in the future, but of which neither I nor any one else knows, or can know anything, as the so-called field lies beyond our line of observation—that is to say, if it exists at all, which no one can prove either one way or the other,—if all this be permitted me, why should it be denied to my neighbour? And if we both enter the field of pure imagination—for what are mere conjectures and assumptions on points upon which we know nothing, and cannot know anything, but imagination?—what can the result be but the crudest of conjectures, the wildest of theories?

It is of importance, then, that the technical student should thoroughly understand that the sciences of physics are dependent upon facts, and those facts in turn depend upon close observation for their discovery, their patient and careful recording, and from them laws are deduced. If he has any physical theory to propound, any process to propound and explain, which he finds he has discovered, let him be sure—quite sure—that he has been and is throughout dealing with facts, with things as they exist and which can be appealed to, and can be verified, used or applied by others as well as by himself. It is by the application of facts that theories are tested; and it cannot be too often repeated that it is to facts, and facts alone, that we owe all our marvels of modern inductive science.

Now, in the study of physical science there are, as in all other departments of study, two ways of following it up—the right way and the wrong one. And that the wrong way is but too frequently followed is evidenced by the confused condition in which what they have studied is presented to and retained by the minds of so many students. On the principle of keeping to one thing at a time in the early stages of the study of physics, the general laws of nature, or what may be called the first principles, should early be communicated to the student. The application of those to specific purposes will be illustrated at a later, in some cases a much later, stage of study. Much of this special application will, indeed, be seen only, when the student has reached and is passing through the stage of apprenticeship or training in practical work, by whatever system that be carried. This special application of natural laws and the various facts and phenomena from which they have, by a process of inductive or Baconian reasoning, been deduced, is a thing of slow growth, and is in fact being taught or added to by daily experience. It so comes about, therefore, that so long as a man is working he is learning.

THE IRON MAKER:

The Details of his Work and the Principles of its Processes.

CHAPTER XVI.

The Manufacture of Wrought Iron (*continued*).—The Lancashire Hearth.

In describing the method of refining iron described in last chapter, we stated that the molten mass was stirred by the rabble rod so as to bring the metal within the sphere of the blast. And as through the action of the blast the refining and decarbonising process goes on, the metal becomes more and more spongy and pasty; and on the process being in the estimation of the "refiner" or workman near completion, the metal is brought up to the surface or top of the hearth and fused into the balls or blooms, which when in proper condition are taken out of the furnace and subjected to the after process of hammering. The large pieces of wrought iron thus obtained are afterwards cut up into smaller portions. These are put into what is called a "re-heating" furnace, hereafter explained, brought to a welding heat, taken out and welded together to form certain sizes, and hammered.

The refining or refinery furnace which was generally employed in this country, and which was, we believe, first introduced by the iron masters of South Wales, was a modification of the Lancashire hearth just explained, in which a double set of *tuyères* and nozzle pipes was used. These were set inclined at an angle of 30°, and the nozzle blew the blast from opposite sides, three *tuyères* as a rule being placed on each side of the furnace. The fuel employed was coke. Fig. 5, Plate CLXXXIV., is a diagram which will give a general idea of the arrangement and mode of working of a refinery furnace of this type. *a a*, part of the furnace, which at upper part was finished off with a "stack" or chimney; *b*, the treadle; *c*, *c*, the *tuyères*; *d*, *d*, the nozzle pipes leading the blast of air from the blast pipes, *e*, *e*. The process of refining the iron by this method is comparatively simple as contrasted with the Lancashire hearth process we have described above. It is not so much of an actual producer of of wrought iron, like the Lancashire hearth process, as a producer of a quality of iron greatly refined or with its impurities passed off in the resulting cinder or slag, which finer iron is by another process finally converted into wrought iron. In some respects this refining process now being considered may be looked upon as a mere extension of the blast-furnace process, inasmuch as, like it, the final product is passed from the furnace in a melted state, not brought into a partly spongy condition and made up into a ball or bloom which is then hammered. In this the later refining, and which at one time was largely used, the cast or pig iron is melted by the blast acting on the coke with which the furnace is charged, and after it is completely melted the blast is continued for some time, varying according to circumstances, but averaging say half an hour, till the oxidation is carried to the required point. This is judged of by the experienced workman, aided by frequent examinations of the melted metal and the cinder or slag formed by the process, and which he takes out by means of a rabble or iron rod. On the refining being completed, the metal with its accompanying slag is run out into what is called a running-out bed placed in front of the furnace and at a lower level than that of the hearth of fig. 5, Plate CLXXXIII. To aid the separation of the cinder or slag from the melted metal, cold water is thrown over the mass as it lies in the running-out bed. This chilled iron—for such it is—is then taken out of the bed and broken up into small pieces, which are afterwards passed through the process of "puddling." Although the refining furnace as here described, or with modifications of it, is still used, giving us a process preliminary to puddling where the best qualities, known in the trade technically as "brands," of wrought iron are required, the system is now almost universally disused; and the manufacture of wrought iron carried on by a process so far totally distinct from it, and requiring therefore a different arrangement of furnace, that the pig or cast iron to be converted into wrought iron when being worked into this product is not allowed to come into contact at all with the fuel, and no current of air artificially produced—that is, no "blast" is employed.

We have seen, in tracing the history of the process of wrought iron production, that the quality of the fuel, in the earliest form of the refinery or "blooming" furnace, was of the highest—that is, charcoal was employed. In the next form, and that generally used in this country, which we may call the melting or "smelting refinery," a less costly fuel was used—namely, coke. We have now arrived at that stage of the history of wrought iron manufacture in which the process can be carried on by the aid of the cheapest and by consequence the most impure form of fuel—namely, ordinary coal. This is used in the "puddling" process, and is now the chief, indeed, the only method used for the production of wrought iron direct from cast iron without passing through any preliminary or refining operation. And it can be so used because, as we have said, the metal does not come at all in contact with the fuel, so that none of its impurities can be communicated to it. This principle gives the chief feature to the furnace employed in the modern method of "puddling"—namely, the giving of two chambers to it; one of these, as *a a*, fig. 6, Plate CLXXXIV., being the furnace proper, in which the coal for

heating is consumed. The other chamber, *b b*, is that in which the pig iron is placed and in which it is worked or "puddled," and the blooms or "balls" formed, which are then taken out and passed through the various processes of the modern method of making wrought iron which will be found duly explained hereafter.

From the relative arrangement of these two chambers it will be observed by the careful reader that the metal lying in the chamber *b b*, technically called the "hearth" of the furnace, is treated solely by the flame and heated gases produced by the combustion of the coal in the furnace proper, *a a*. As these heated products from *a a* pass on their way to the flue *d d*, leading to the stack or chimney, or to the steam engine boiler, which the waste gases in economically conducted works are employed to heat, over the chamber *b b*, which is separated from *a a* by the "bridge" *c c*, they are caused to beat down upon the metal partly by the deflecting action of this "bridge" and partly by that of the surface of arched or inclined roof *e e*. This beating down or reverberatory action of the flames and heated gases from *a a* on the "hearth" *b b* has given the name "reverberatory" to the "puddling" furnace; although the first of these names is now nearly lost in the latter, which is that almost universally employed in the trade, for every one knows that a puddling furnace on the now generally employed system of producing wrought from pig iron must be "reverberatory." It will be observed that in the diagram of puddling furnace given in fig. 6, Plate CLXXXIII., the chamber or hearth is shown with a dotted lining. This represents what, in the technical language of the "puddler," is called the "fettling." This is a mixture of "basic" substances, the principal one employed being an oxide of iron. This, under the great heat, melts or partially melts along with the pig iron, and forms with the cinder what is called a "bath," in which the puddling process is carried on. As this lining (which varies in composition, as pure oxide of iron is not attainable) becomes partially melted and is removed with the cinders, it follows that it has frequently to be renewed. The "fettling" of his furnace "hearth" comes to be an important part of the "puddler's" work; and it is in connection with this part of it that the nostrums of puddlers, known to the trade as "physics," the employment of which is said to produce wonderful effects in increasing the yield or the quality of the iron, play so important a part. At any rate, this is presumed by the puddlers themselves, who throw around their "physics" the shield of a close secrecy, each man professing to have his own particular physic, which "beats all other physics hollow," and the knowledge of which he keeps with jealous care. It scarcely requires to be said that there is little necessity for making any mystery of these nostrums of the trade. They may be said, as a whole, to possess little or no value, or if they do possess this, it is in virtue of their being composed or partly composed of substances which are well known to chemists, and known also to possess some influence on the yield and the quality of the iron. At the same time there is this to be said on the subject,—that in many processes there is always some "trade secret" so called, some mode of working which experience alone can have discovered or shown the value of, which secret cannot always be explained by scientific principles. And, as bearing on this, a suggestive story is told of an able chemist who went down from a learned city to teach science to the iron workers of the Black Country, and who possessed, or is said to have possessed, a lofty scorn for all mere trade nostrums, and was about, as 'tis also told, to show the utter uselessness of such "old wives' fables," and the worthlessness of the so-called "physics" for fettling puddling furnaces—and to show also what science could do, and do so much better. And, as the story further tells, the chemist had to return to the place from which he came, if not a wiser at least a sadder man, inasmuch as his science, accurate as it was, could do nothing either in showing the absurdity of the fettling "physics" of the iron puddler, or how to provide scientific substitutes for them.

The main principle involved in the process of puddling consists, as we have already explained, in the oxidation of the carbon contained in the pig iron. This is accomplished partly by means of the union of the oxygen of the air with the carbon, and partly by combination with the oxygen contained in the cinder or other oxides added to the furnace during the operation. Now, in this removal by oxidation of the carbon, a certain amount of the iron always undergoes oxidation at the same time. It is necessary that the formation of an infusible oxide on the iron should be prevented when the balls are collected together for the purpose of being welded into larger ones; for if this happens, it is evident that the process of welding will be greatly retarded. Silica easily unites with iron protoxide, forming a fusible silicate "with which two pieces of iron at a welding heat may be coated, and yet weld soundly together under pressure, the interposed liquid silicate being expelled in a greater or less degree, having *clean, bright* metallic surfaces to come in contact." The tribasic silicate of iron does not act upon pure iron at a strong heat, but would rather keep it from contact, and therefore from oxidation. "Accordingly it is sought to produce in the puddling furnace," says the same writer quoted above, "a silicate of this kind, which is termed 'a welding cinder.'" The silica needed for this purpose is obtained from several sources: the silicon contained in the pig iron itself supplies it, as well as the sand

which the pig iron has always attached to it when cast in sand moulds; the materials of the furnace bed also supply it. Much could be written on the subject of "puddling," but what we have given, taken in connection with various statements as to the making of cast or pig iron in preceding chapters, and of steel production in the chapters of the series devoted to that subject, and given under the title of "The Steel Maker," will convey to the reader nearly all that it is necessary for him to know.

The Puddling Process in the Wrought Iron Manufacture (*continued*).

The preceding paragraph has been taken up with a description of the important process of "puddling." the first of the series of operations by which wrought iron in its various conditions and forms is prepared for the market. In this description an endeavour has been made to embrace all the points calculated to make clear what the process is by which the metal is changed from the crude pig iron into another form possessing working characteristics which enable it to be used for a wide variety of purposes for which in its form of cast iron it is wholly unfitted.

The work of the puddler is, strictly speaking, confined to one operation—namely, the production of the lumps or masses of metal technically called "balls," and sometimes, though rarely in this country, "blooms." But this involves what may be called a series of operations, all of which demand for their proper execution not only an amount of physical exertion which, as we have said, exceeds that of any manual labour in the wide range of technical work, but the exercise of a high degree of skill, and a thorough knowledge of the materials with which he has to deal.

When the metal in the hearth of the puddling furnace is brought by the oxidising and stirring process into the proper condition—that is, when it is, as it is technically called, "brought to nature," it is gathered up or formed by the puddler with his rabble into the masses known as balls. Each ball as it is formed is not at once withdrawn from the furnace to be passed through the next operation or process in sequence; but after preparing one ball he lays it aside within the furnace, until he proceeds to and finishes the making of two other balls. Each ball as it is made must be protected, while it lies in the furnace, from the active agency of the oxygen of the air present in the furnace, as this would oxidise the iron, or in other words would burn it and thus reduce its quantity while lowering its quality. To protect the ball from the oxygen, it is therefore covered over with or made to lie in the cinder of the bath, and this while placed near the bridge of the furnace. While the first process of puddling is being carried on—that is, the stirring up or the rabbling of the metal, and washing it in the cinder-bath—a bright smokeless heat is required; but on commencing, and while carrying on the "balling" up process, what is called a "reducing" heat is necessary. This is obtained by decreasing the draught of the furnace, and by adding a fresh supply of coals, and so manipulating them near the furnace door that together, in place of a bright, clear flame or heat, they produce a smoky one, largely impregnated with what we call soot, or with carbon not consumed. The object of this reducing heat is to prevent the iron or metal of the balls being burnt, or wasted and deteriorated in value, while at the same time the heat is high enough to keep the ball at the proper temperature required for the succeeding process through which it is passed. Taking up the first ball and manipulating it with his iron rod, to which it is welded or adheres, it is taken out of the puddling furnace and carried to the first of the machines, by which the metal is prepared in its condition of wrought or malleable iron for the market, after it issues from the puddling furnace. The work of the puddler, as the workman who does the work connected with the process is called, is so exceedingly severe, not merely from the hard physical labour involved in moving the heavy lumps of metal, and management or stoking of the furnace itself, but also from the excessively high temperature to which he is exposed, that numerous attempts have been made to do his work, wholly or partially, by the aid of special mechanism. Costly as have been the trials made in this direction, none of the machines brought out have in the true—that is, in the commercial sense of the word—been successful. We do not think the reason is far to seek. The puddling process is *not* purely a mechanical one; it involves on the part of the "puddler" or workman a large amount, if not of intelligence, at least of careful attention and observation, so that he adapts in a varying way his work to the varying circumstances of the materials he has to deal with. This involves the element of mind, or thinking. Now, automatic or self-acting machines designed to supersede manual labour can only do so where the circumstances of working are invariable,—a machine cannot think. Being partly a mechanical process, partly one demanding intelligent care, we believe the process of puddling will be mechanically aided only where the mechanism does part—say the most laborious part—of the work, and the puddler with his personal skill and care the other.

Processes of the Wrought Iron Manufacture following the Puddling—The Shingling of the Puddled Blooms.

In preceding paragraph, in describing the process of puddling, we arrived at that part of it where the operation was completed and the puddled iron formed into separate masses or lumps, to which the name of "balls" are given,—although they are not. as the name would seem to indicate, spherical

form, but are in shape of a parallelogram, or they may be more familiarly described as having a shape somewhat like a baker's (" brick ") loaf, the length of which is greater than its end or cross section. When we state that the weight of the balls is very considerable, varying from fifty up to as much as eighty pounds, and that the handling of these by the rabble or iron rod is carried on in front of a mass of fuel and metal at such an exceedingly high temperature that the light it gives is so dazzling that one unaccustomed to it cannot look at it for more than an instant, and that only painfully, the reader will have some conception of how hard and exhausting the puddler's work is. When the balls are ready they are withdrawn from the furnace; they are taken from it and carried to the first mechanical process by the puddler's assistant or mate, termed the "under-hand." For the work of the puddler is too important for him to be taken from it to perform the simpler duty of merely carrying the ball from the furnace to the "shingling" process, which is the first of the purely mechanical operations through which the puddled iron is put and formed into bars, rod rails, and plates. The shingling process, or blooming as it is sometimes called, is one of simple hammering; and its object is, in the first place, to squeeze or force out the "cinder," which flies in all directions in the form of showers of brilliant sparks or flakes; and in the second to give to the mass of iron thus partially freed from its cinder a certain degree of consolidation, to fit it for the succeeding processes. From the mere size or solidity of the "ball" the reader will perceive that very ponderous blows must of necessity be given to it, in order that the whole mass may feel the effect of the squeezing-out influence of the hammer. The first form which the machine-wrought hammer took was that known as the "tilt" hammer. The character of this ponderous implement, as used in the "shingling" of the "ball," and the mode by which it is actuated, is illustrated in fig. 1, Plate CXC. In this *a a* is the "helve," corresponding to the handle of the hand hammer. This works on a pivot supported or carried by the pedestal *b b*, which with the anvil *c* is firmly secured to the foundation *d d*, which is very massive, and is built with great care in order to resist the powerful impact of the hammer on the anvil. Some idea of the force of the blows which the foundation has to resist and meet, and also of those which the ball receives as the hammer descends upon it, may be had when we mention that the hammer, including the "helve" *a a* and the "head" *e e*, weighs between four and five tons, and is worked at such a speed that it gives a shower of blows at the rate of a hundred and fifty per minute. The hammer is lifted or "tilted" up, and allowed to fall through a distance or vertical height sufficient by the momentum of the falling mass, *a a*, *e e*, to give the force to the blow required. This tilting is effected by the revolution of the wheel or drum *f f*, to the periphery of which "wipers" or projecting parts, *h h*, with curved sides as at *k* in separate diagram in fig. 1, Plate CXC., are fixed. As the drum *f f* revolves in the direction of the arrow, the wiper *h* coming in contact with the edge or under side of hammer head, as at *l* in the separate diagram, lifts the head up, and when the wiper passes by the revolution of the drum from contact with it, the head *e e* and helve *d d* fall, the head or hammer proper, *e e*, striking on the "ball," which we suppose to be lying in the anvil *c c*. It will be observed, on inspecting the figure, that the upper surface of the anvil *c c* and the lower surface of the head or hammer proper *e e* are not flat, but are provided with projecting parts and corresponding indentations. This is a modification of the well-known but exceedingly useful appliance of the ordinary blacksmith known as the "swage," for giving surfaces corresponding to the facets or surfaces of ordinary hammers known as their panes; and is used in the tilt hammer operation by the "shingler" (the workman superintending the hammering or shingling of the ball being so called) to give certain effects, and to give it such a form as to enable it to be passed through the next process, or that of rolling. The iron bar or rod by which the under-hand or mate of the puddler carries the ball from the puddling furnace to the tilt hammer is by its first blow firmly welded to the "ball," so that it affords a handle by which the "shingler" or hammerman can manipulate the ball under the blows of the hammer. According as the ball is placed in relation to the undulations and projections on the head *e e* and anvil *c c*, the ball is increased in length or in breadth as desired, till when finished it has a length of about twenty inches and a thickness of four or five. The roughness given to the surface by the indented parts of the head and anvil are smoothed down by the hammer while the bar lies on the flat-faced portion of the anvil. Only a comparatively small number of blows is required to be given to the ball in order to give it the form of a rough bar, which is ready now for the next or the "rolling" process. The form of tilt hammer illustrated in fig. 1, Plate CXC., although occasionally in some parts still to be met with, has been largely and practically almost superseded by the "steam hammer"; but we give it here as it illustrates the general principle of "shingling."

After the shingling or hammering, the bloom is, as just stated, passed to the next operation in sequence —namely, the rolling. The rolls here employed are termed "shingling" rolls or rollers—sometimes the "roughing rolls."

THE CABINET MAKER.

The Technical Details, and the Principles affecting the Design of his Work.

CHAPTER IV.

At conclusion of last chapter we offered some remarks as to the honesty of work. And much as we may now talk of this cause and that cause, to account for the decay of trade and the various ills which on all sides are admitted to affect callings of all classes, we fear that this cause is but too often overlooked,—the lack of pride, or rather we should say of principle, on the part of the workman in his work; nor less should it be here added, on the part of his employers who *sell* what they know not to be good and true. It would be well, when we are singing pæans of praises in honour of our high civilisation, to remember the period in which, if civilisation, as looked at from our point of view, was low, principle and the exercise of it was high, and held in high esteem. This consideration applies to us all—workmen by the hand, workers by the brain—earnestness and honesty of purpose and of life, even in the meanest of work, are what alone give value to it.

The Character of the Materials used in the Making of Furniture a Point of Great Importance.—Old-fashioned Work as compared with New in this respect.—Practical Lessons to be learned from this.

But not less marked in the furniture of our forefathers was the materials they used. Common sense enough they had, if they sometimes lacked our artistic sense; and this common sense told them that it was but folly to put the highest class of workmanship, which would last for generations, upon material which, being of poor quality, would not live out half the period. The "stuff" they used then was of the best; and of many of our furniture makers it may be said that they also are wise in their generation, and use also, in their view of the matter, their common sense too. For, knowing that the workmanship they give to the articles is calculated to keep the articles together only sufficiently long at least to hold out till they can be "sold," they wisely give materials which are quite in keeping with the workmanship. They very naturally argue in a way the converse of the old honest workman, and conclude that it is folly to give materials that will last so very much longer than the bad workmanship which serves to keep them together for the very minimum of time. Both as regards workmanship and materials, a large proportion of our modern furniture is thus and therefore practically worthless. We do not here enter into a consideration of the question how far the blame of this is to be laid on the maker and the seller, and how far implicated in the matter is the purchaser. No doubt the rage for cheap things simply as such, without any, at least without a due regard to their true worth or their utility, does lie, to a large extent, at the root of the system which admits of bad work and worse materials being sent out. Those who live by the system assert that this desire on the part of the public for cheapness actually *compels* them to give bad work and materials. They maintain that they give honestly full value for the money they actually receive from purchasers; although they know well enough that the whole transaction is practically a mockery, for the articles are not what they pretend to be—they possess no true utility. "Cheap and nasty" is a well-known phrase, and by no means elegant withal in its terms; but it would be well if purchasers of furniture would bear in mind, oftener than many of them do, the lesson which it conveys. So also that of its paraphrase, as given in the other saying, "the dearest is cheapest." At the same time, the contrast as between the makers of this modern so-called furniture, which furnishes the purchaser with what he finds but too soon to be a "delusion, a mockery and a snare," and the makers of the old-fashioned furniture we have alluded to, conveys a lesson to us of some worth.

The Influence of a Desire on the Part of the Public to have Cheap Work on the Progress of the Art of Cabinet Making.

The old honest workman could not if he would give bad work; and if he could would not in any wise have given it. But, in the high integrity of his character as a workman, with whom work in the highest sense of the term was a thing which had to be done in reality, not in fiction, he could do no other than give the very best workmanship of which he was capable. The rage for cheapness, if it existed then—which we have very good reason to believe it did not—did not affect him. To its claims, if ever they were presented to him, he would and did have but one reply: "I do not give you bad work, for bad work I cannot do, and would not if I could; if you cannot pay the price for it there is no more to be said—no money, no work. My work is of the best; it is worth your money. I offer only a fair exchange." All such considerations, some of our readers may say, are purely moral and social, and have no practical concern with the subject in hand. We crave the pardon of such, if such amongst our readers there be—which, however, we take leave to doubt—for saying most explicitly that such considerations *do* affect the subject in the closest possible manner. The morality of the trade, the *morale* of the workmen, constitute simply its vital principle. This principle and the merely mechanical work cannot be divorced: if a separation be made, it means only ruin to both; and it will surely be admitted that the result of the execution of work depends for its value wholly upon the principle upon which the work is executed. The work done is surely influenced by the way of doing it; and it will further be admitted that

if the moral and social considerations were, as a rule, taken into account and followed out, the dissatisfaction which so widely exists between makers and purchasers would cease to exist. We may not always be capable of reaching to a high standard, but we are much more likely to reach it if we are convinced that it would be and is a good thing for us if we *could* reach it. To aim high is incumbent upon us all, and we should assuredly consider ourselves worthy of grave censure if we omitted to place before our pupil readers, be they youths or men of mature years, all the considerations which affect the highest interests of the callings which occupy the cares of their daily lives, and upon which their onward progress and true prosperity depend.

Utility in Furniture—How it may be Sacrificed.

We have said that utility is an essential point to be considered in the designing and construction of furniture—that is, that if it be not really useful and fitted to serve the purposes it professes to serve, it may, for all practical purposes, be left unmade. If the watch I buy does not go, or, if going after a fashion of its own, goes so badly that in place of guiding it misleads and betrays, I may as well save my money and refrain from purchasing it—unless I buy it for the mere look of the thing; but at the best it is a make-believe, and I do not practically possess that which I seem, and only seem, to have. It reminds me of the Irishman who was put into a sedan chair which had no bottom: ostensibly carried, he had to carry himself—and, as he sagely remarked, "Had it not been for the name of the thing I might as well have walked." Better! but for the reputation, such as it was—his encaged and confined walk could not have been of the most comfortable. One may well apply this grotesque story to the subject in hand, and ask how often one might as well not have articles in the house, but for the name of the thing, the reputation, or the look of the thing?—for, in reality, they possess no utility. There are many households in which articles of furniture are put aside in some situation from which they cannot easily be taken out for use, simply because they are of "no use," for all purposes for which they are designed being utterly worthless; they *may* be there for ornament, but certainly not for use. This may arise, and does generally arise, from disgracefully bad workmanship and as disgracefully bad materials. But "utility" is often lost sight of in other ways—for utility, as we have seen, carries with it more points than one. The designer should always ask himself, in beginning his work—"What are the uses for which this article I am about to design, and afterwards to make, is really designed? what are the requirements of the user which it should meet? If I used it for myself, what qualities should I like it to possess? It is my duty to think of every possible contingency which may arise affecting its use." If this were done as a rule, the cases in which fitness and convenience are almost totally lost sight of would not be so numerous. Mistakes in design, errors in workmanship, in nine cases out of ten, arise from pure thoughtlessness.

Practical Examples of Defective Design in Furniture Destroying or Lessening its Usefulness.

Articles are not only made so as to be inconvenient in handling, but uncomfortable when used. Some are made so as to be the cause of disagreeables; some positively possess dangers, from which more than one of our readers, we feel assured, have suffered. Articles of furniture, with which people in bustling about are apt to come in contact, are made with the sharpest edges at their corners, or with carved ornaments in such high relief that they yield sharp points, which are not only but too frequently catching objects of dress and tearing them, but are the occasion of many a severe bump or blow, which children, especially, suffer considerably from. We have seen an iron bedstead so designed and constructed that it was more than inconvenient—it was positively dangerous. In one example the whole of the ornaments were so designed that they afforded a forest, so to say, of projecting points, which were perpetually catching clothing; and we have seen a garment, perhaps but too hastily taken up, ripped up from end to end by catching one of these projecting points. Worse than this, we have seen examples of bedsteads so designed by way of ornament, and so constructed and finished, that projecting parts, having edges as sharp as knives, acted not seldom as dangerously. Conceive of such a *chevaux de frise* of cutting edges being placed within all too easy reach of a sleeper's head; an uneasy movement, which might occur at any moment during helpless sleep, might result in his cheek or hand being ripped up by an ugly wound inflicted by one of these sharp edges. We do not exaggerate: we remember seeing at an hotel a bedstead bandaged like a hospital patient, here and there with white linen neatly wrapped and tied with coloured ribbon. We asked the reason, and were told that till it was replaced it was so treated to prevent a recurrence of a somewhat grave accident, which had happened to some hasty or unlucky inmate of the room, who had his hand most severely lacerated by one of those sharp cutting edges with which the thoughtless designer had adorned it by way of ornament, and which the equally thoughtless workman had sent out without all those projecting points being in some measure at least toned or blunted down.

THE STEEL MAKER.

The Details of his Work—The Principles of its Processes—The Qualities and Characteristics of its Products.

CHAPTER XV.

At the conclusion of last chapter we stated that the ease with which large weights of melted metal are dealt with is one of the marked features of steel making. So marked is this, that he requires to think for some time that the men employed are dealing not only with a most dangerous material, but weighing many tons in the mass. And yet the whole is handled, so to say—this is the only expression we can use—with such ease, and with such precision of detail, that it might be handfuls a few ounces in weight with which they are concerned, and as innocent in nature as cold water or sand. Yet how dangerous the work let those tell who have known it practically for long, and been mixed up daily with it. You may ask an experienced manager not if accidents ever happen, but if they happen often; in the shrug of his shoulders, if a stolid business man, reticent as all business men—in the involuntary shudder, or the shade which passes over his face, if withal a kindly man—you may form your own conjectures what accidents must be when they do happen, and that they happen more frequently than the general public are aware of. It is almost the literal truth that those in daily work at Bessemer steel making "hold," to quote the graphic phrase, "their lives in their hands,"—a truth not altogether inapplicable to strangers who may be only spectators of the blow, as more accidents than one have unfortunately testified.

The direct method of taking the molten pig iron from the blast furnace and conveying it at once to the converter to be changed into steel, can, of course, be carried out only at works in which blast furnaces for the making of cast iron are continually in full blast. In districts and at places where this dual condition of working does not exist, the indirect method, in which the cupola is required to re-melt the pig-iron before it can be put into the converter, must be adopted. The general arrangement of a Bessemer steel works in which the cupola forms a feature is very much the same now as that originally introduced. And this remark applies more especially to the mechanism of the plant; for, as we have had occasion to observe, Sir Henry Bessemer had so completely thought out the mechanism best adapted to his process, that very little improvement has been made in it, and that where made it has been more in details than in principle. So that it is only to the expert in this department of work that there appears any difference between the plant, including the mechanism, of works which were erected years ago, and those which have been but recently set to work. The plan, then, which we give, with accompanying details, illustrate the first or early works planned by Sir Henry Bessemer himself, already described and illustrated by figs. 1 to 6.

Practical Working of the Bessemer Process.—The Converter.

It does not come within the province of our series of papers to enter fully into the details of the mechanical means employed to carry out the processes of steel making, which are chiefly occupied with details affecting closely the nature of the processes themselves; still it will be useful to draw attention to some parts connected with their mechanical features.

And first as to the "converter" vessel itself.

As stated by the inventor in his paper, part of which we have already given, one of the great difficulties attendant upon the perfecting of the details of the process arose from the converter, as it was at first found impossible to get a material for its lining which could withstand the intense heat which the process created. This heat alone was not, however, the only distinctive agency by which the fire-brick at first used for lining the converters was damaged; the dissolving action of the slag was much worse than the mere heat, high as the temperature of that was. This action of the slag was so powerful and rapid that a thickness of fire-brick lining of three inches has been known to be dissolved or destroyed by the slag in the space of thirty minutes, which was then the average duration of a "blow," as the operation of converting a vessel full of the metal is sometimes called. The difficulty was got over by applying a material called "ganister," abundantly found in the neighbourhood of Sheffield. This substance plays so important a part in all metallurgical processes in which intense temperatures are required to be withstood, that a brief notice of its peculiarities will be interesting here. Ganister is a mineral substance composed chiefly of silica, with a small percentage—about a hundredth part—of lime, and of albumina; it may be defined as fine particles produced by the grinding down under natural action of quartz rocks. Ganister has a waxy or glassy like fracture, not like the granulated and dull surface of ordinary sandstone, which it does not at all resemble. It is very hard and tough, and is capable, unlike all other sandstones—with which some class it—of being worked up under moisture into a compact, solid, and close plastic substance, precisely as the dried particles of clay can be worked up into a plastic substance or body, under moisture and pressure. It is this property of being kneaded which, combined with its capability of standing the highest practically attained temperatures, or its high "refractory" qualities, which gives it such value as a material for lining vessels, or for being used for purposes where resist-

ance to great heat is to be sustained. The geological position of ganister is just below the coal strata, thus generally underlying the coal measures. It is found in comparatively large beds in Yorkshire, the most productive bed yet worked being at Penistone, on the Manchester and Sheffield railway. The ganister found at this place, and also at Sheffield, but a few miles distant from it, is of the highest quality.

In lining the converter the ganister is, when worked up into the clayey-like condition, forced or squeezed into the ring-like space left between the sides of the vessel and a central mould placed in it. The converter is formed in two parts, which greatly facilitates the lining, and when the lining is completed those parts are secured together by bolts and nuts. The lining is dried by the combined use of first a coke fire lighted in the interior of the converter, and afterwards this urged gently by the blast passing through the perforated bottom. The part of the converter lining which wears out most rapidly is the bottom, with its *tuyères* through which the blast is forced; it requires to be renewed frequently—often every tenth "blow" or working, according to circumstances. To renew the bottom under the old system of working, the converter had to be cooled down, when the bottom was relined. The time lost and expense incurred were successfully got rid of by the American metallurgist, the late Mr. Holley, who devised a system of making the bottom quite independent of the body of the converter. By this means the old worn out bottom could be taken off at once, and a new or fresh lined bottom put in its place, thus avoiding all delays in the cooling down of the converter as a whole, and doing the work of lining much more quickly than in the old system. The joint between the bottom and the body of the vessel is made good with ganister, which can be forced into it from the outside, thus saving time.

Practical Working of the Bessemer Process.—The Casting Ladle.

A very important part of the Bessemer apparatus is the turning or casting ladle. This receives the molten steel from the converter, which is tipped over, as explained in a preceding chapter, in connection with figs. 1 to 6 inclusive; and the "ingot moulds" are filled from this ladle. This, shown in section, in fig. 6, in the act of pouring the steel into the ingot mould, is that designed by Sir Henry Bessemer at the early period of the history of the process, as described in a preceding chapter, and illustrated by drawings figs. 1 to 6. Several improvements have, since that early period in the practical working of the process, been made, chiefly with a view to facilitate and control the flow of the melted steel from the body of the ladle, into which it has been poured from the converter into the ingot mould, placed in the ingot pits, as shown at *h* in fig. 4. The general details of the arrangement, and working gearing of the crane by which the casting of the ingots, or the shifting of the position of ladle from one ingot to another, remain very much the same as designed by Sir Henry Bessemer. We have already alluded to the facts that, so thoroughly had he thought out the system as a whole, and so well adapted his mechanism to its requirements, that it remains practically unaltered at this day. Many details have been improved, but the main features remain unchanged. The following description will give the mechanical student a fair idea of the general arrangements. The casting ladle, the body of which, it is scarcely necessary to say, is of iron, is lined with a strong clay loam. The ladle is itself supported in its frame by—and is capable of being swung or tilted, when in the act of "teeming" its contents into the ingots, upon—side trunnions. Those are placed at points of the ladle side coincident very nearly with the centre of gravity of the ladle, when it contains its full charge of the melted steel from the converter. This arrangement reduces the power necessary to tilt over the ladle when "teeming" to a minimum. The casting ladle thus hung on its trunnions is swung or suspended from the end of the jib of the casting ladle or ingot hydraulic crane. This jib, as shown by the drawings referred to above, is carried by and placed upon the upper extremity of the crane post *h h*, fig. 3. The teeming hole through which the molten steel passes from the ladle to the ingot mould is closed when required, and a refractory plug fixed at the end of a rod, which is also covered with a refractory substance to resist the heat of melted steel. The rod is moved up and down this, opening and closing the teeming hole by the levers as shown.

Debasing Constituents in Iron Ores used for Steel Making.

In the course of our remarks, both in this present series of papers and in the companion series, entitled "The Iron Maker," we have had occasion to refer somewhat frequently to the constituents or elements present in iron ores which lessen their value as sources of metallic iron of good quality, and this from the debasing or deteriorating influence which they exert. The reader will find those debasing constituents of ore detailed, and the way in which they influence prejudicially the metal obtained from the reduction of the ores, under the head of "The Iron Maker." From what is there said, as well as from remarks more or less direct in other parts of that paper, and also in the present series of papers, the reader will perceive that of all the debasing constituents present in the ores of iron, those of phosphorus and sulphur are the most dreaded by the iron master, and by the steel maker more especially. How they act on the metals produced in the processes of both

of these we have already in the appropriate place explained. Affecting powerfully, as those debasing constituents in ores do, the commercial value of the metals produced from them, the reader will easily understand how it is that the successful solution of the problem how to eliminate cheaply and quickly phosphorus and sulphur from iron, and from iron used in the production of steel, has for long engaged the attention of practical metallurgists and of scientific men. In view of the enormous supplies of ores possessed of but too high a percentage of those debasing constituents, and of the amount which could be realised if those constituents could be got rid of cheaply and quickly, the prize which could be secured by the discovery of a successful system has been worth striving to obtain. How it has been attained, and as it is now proved, as we believe beyond all doubt, most successfully, we now proceed to show. The subject is one not merely of such direct pecuniary or commercial importance, but carries with it much that is of great interest looked at from the purely metallurgical point of view.

The Thomas-Gilchrist Process of Dephosphorising Iron Ores; otherwise the Basic Process.

This process of dephosphorising iron ores, which bids fair to revolutionise the iron and steel trade, is known as the Thomas-Gilchrist. It has for a long time occupied the attention and engaged the business interest of a large number of those directly connected with the iron and steel trade. Circumstances are not wanting to show that that attention will be more widely given to it,—that the practical interest of business men will be still more extensive. And this is likely to be so; for unless the first scientific and practical authorities connected with the iron and steel trade be mistaken, and unless (which is indeed still less likely to happen) the indications at present afforded by the practical working of the process be altogether changed, the Thomas-Gilchrist process is likely, although in another direction, yet singularly enough in more or less direct connection with its use, to as completely revolutionise the trade as the Bessemer process did. And that this opinion of scientific and practical men is well founded, everything around us indicates, even making all due allowance for such perhaps slightly over-coloured statements made or over-sanguine views respecting it held by some who are disposed to make the most of a new thing which strikes their imagination or engages their business interests. It must be confessed that this class is numerically very small in connection with any new process, and all the smaller is the number the more pretentious the process is, the more important the work which it proposes to do. The majority is all on the other side; and indifference, prejudice, class interests and personal pique all combine to form an opposition to any new process or invention, which is all the stronger the higher its claims are to public notice. All branches of our industrial work abound in examples of this latter condition of matters; and, as we have seen, the iron trade is not marked by having so very few of them—some, indeed, the history of which is a blot on the fair fame of our industrial workers. The Thomas-Gilchrist process at one time had a very narrow escape from being an addition to the list—all too long—of methods of working of the highest value being lost to the nation by pure indifference and neglect. At and for some time after the announcement of the discovery—for it comes, if not quite, more within the range of discoveries than that of inventions—success seemed very likely to be rendered impossible; and this not from any opposition of a direct kind from practical men, not from any disquisition more or less laboured showing the errors of the discovery from scientific men, but simply from neglect and indifference. In short, it was very much treated in that way but too well known in one or other of its aspects to all men who have had large experience of life, which indicates that men think so very little of a thing that it is not worth while to take the trouble even to condemn or refute the claim which it makes to notice. And of all methods of treatment this is the hardest for men to bear. One can defend oneself when attacked, nor is one's self-respect or esteem lessened; but not to be thought worthy of being attacked at all is quite another thing. He is a poor man indeed who possesses nothing which the thief thinks worth robbing him of.

In the history of any new process it is comparatively easy for men to understand its general principles; but it is not given to every one to grasp its possibilities or potentialities of success. In all great discoveries it may, indeed, be taken as a rule that their results ultimately far exceed the expectation or even the most sanguine hopes of their discoverers. Something flows out of them which even they did not dream of,—just as a man travelling in a hilly country conceives at some commanding point that he has within his vision a view of the whole region surrounding him; but has only to reach some higher point, or even but to change the outlook from that which he at first occupied, to find a wider range or newer aspects of view. One thing leads to another, and there are but few successful discoverers and inventors who are not astonished, at the end, how different the position their work has assumed, compared with that which it occupied at the commencement of their career.

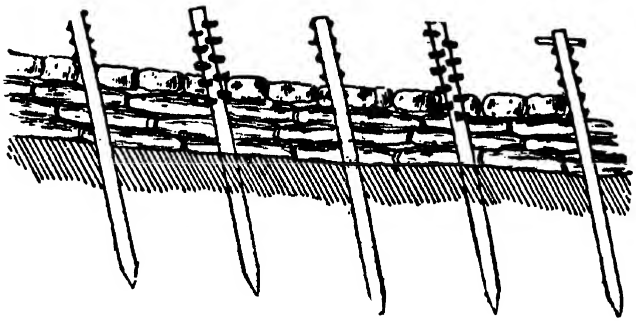


FIG. 1.

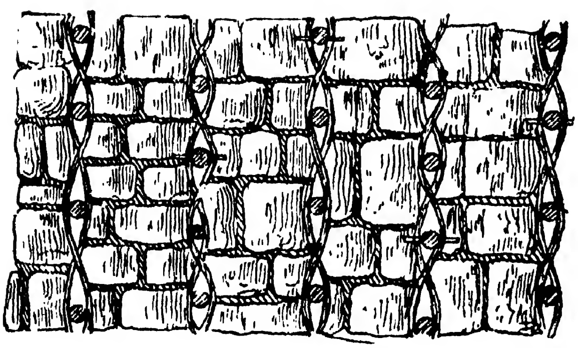


FIG. 2.

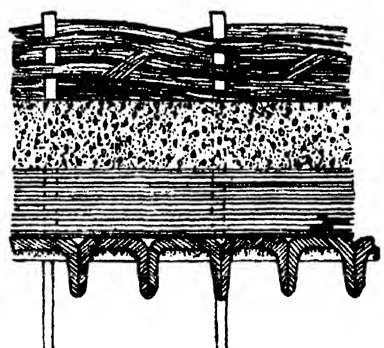


FIG. 3.

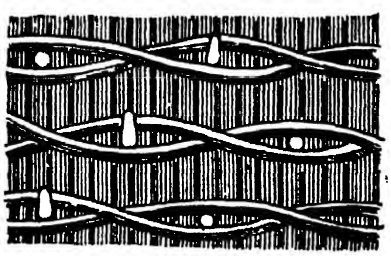


FIG. 4.

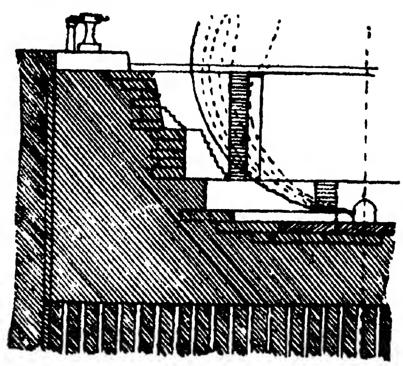


FIG. 5.

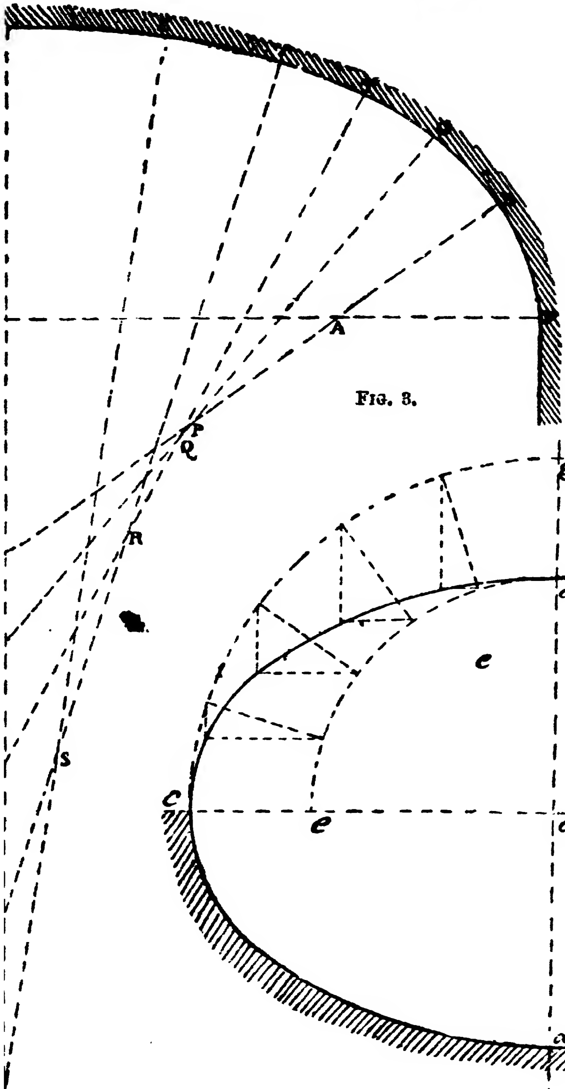


Fig. 3.

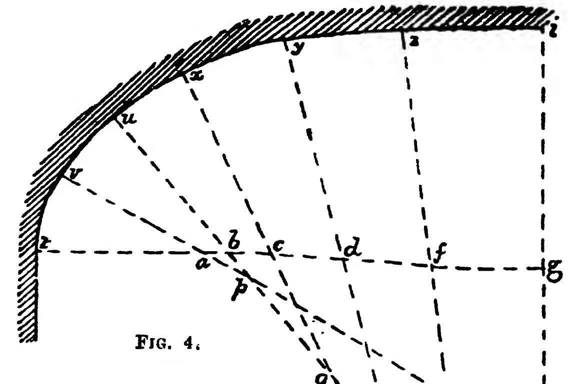


Fig. 4.

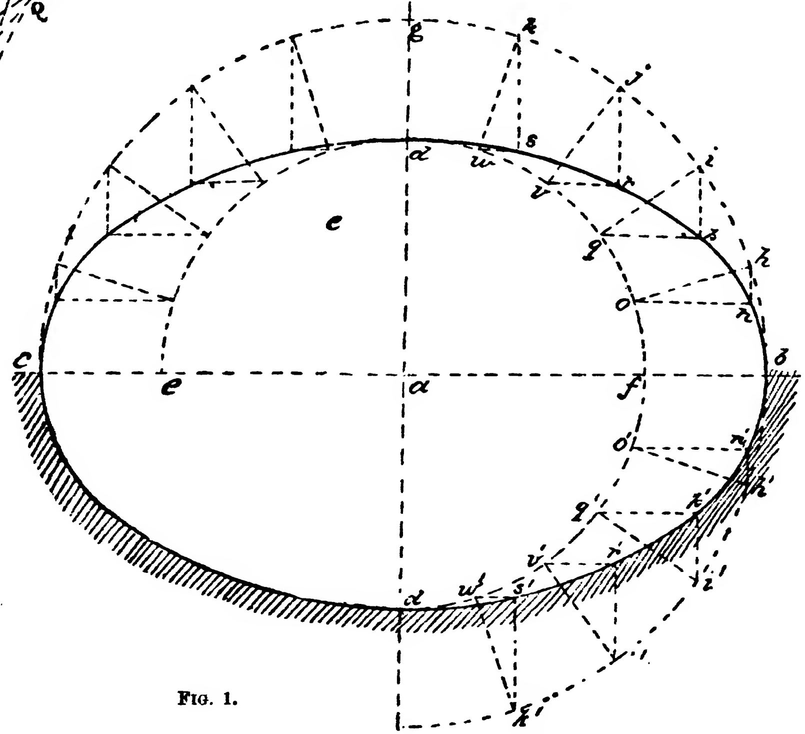


Fig. 1.

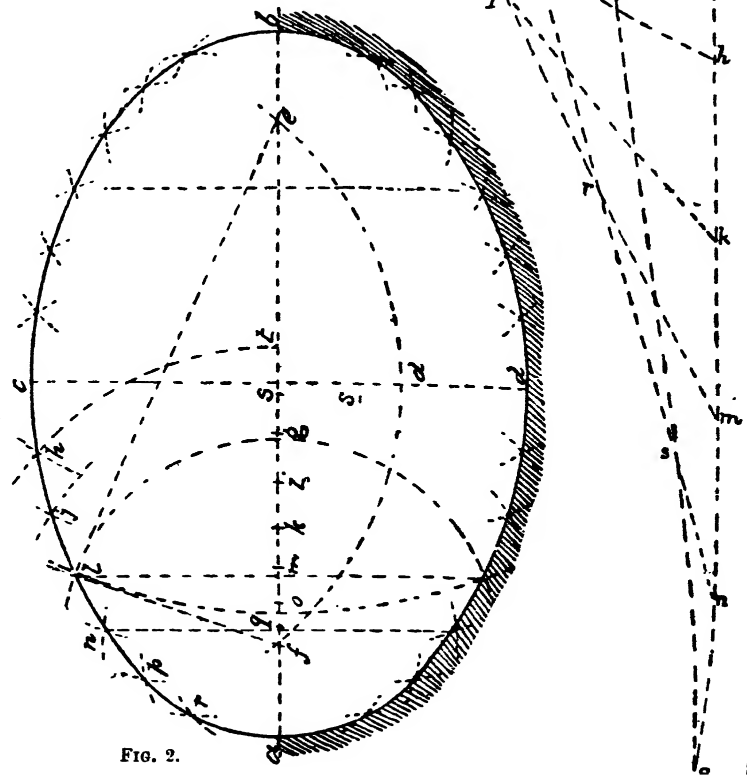


Fig. 2.

ELEMENTS OF CUT-WOOD WORK.

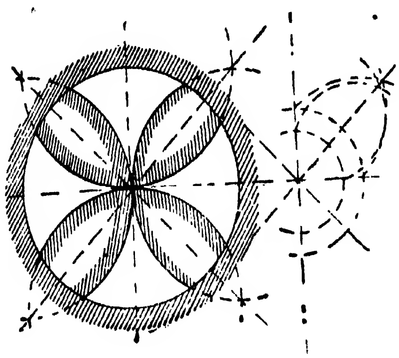


FIG. 1

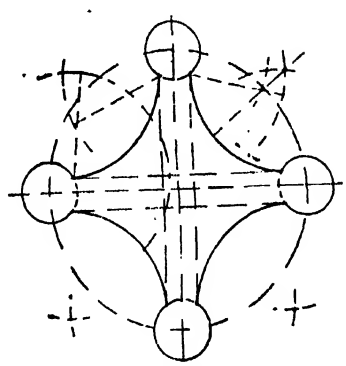
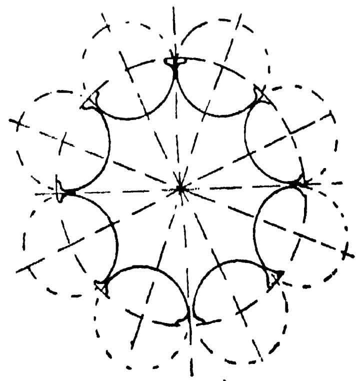


FIG. 2.



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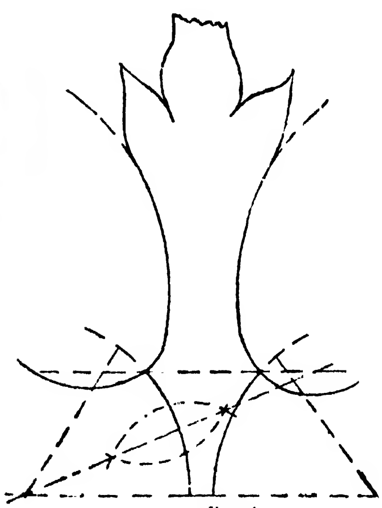


FIG. 4.

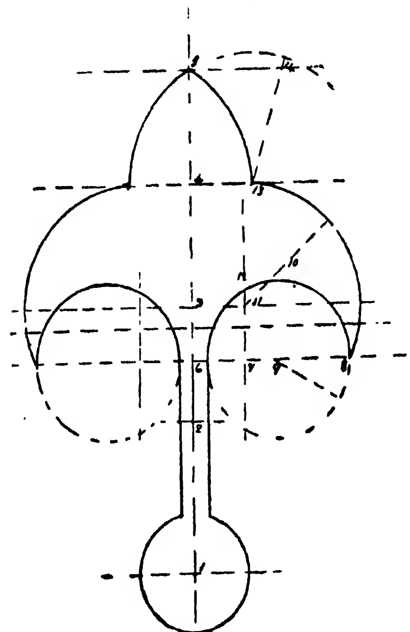


FIG. 5.

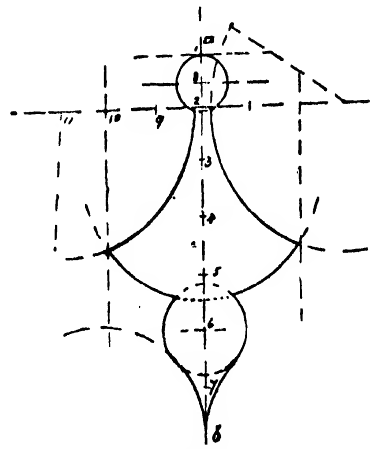


FIG. 6.

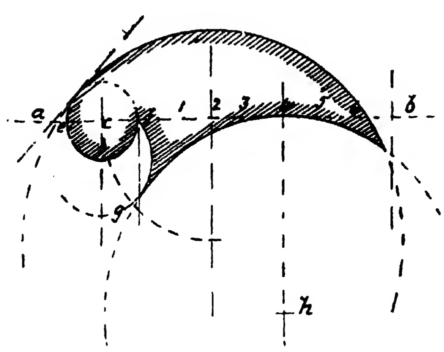


FIG. 7.

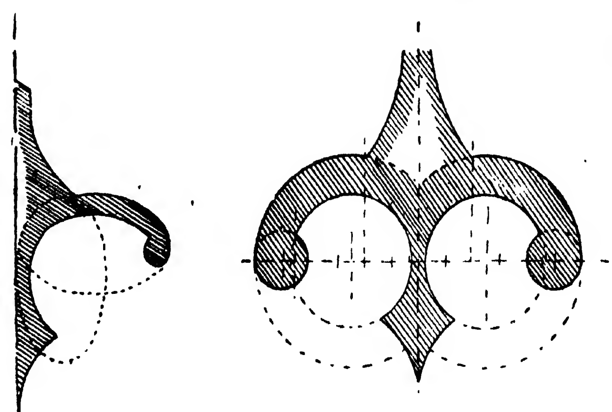
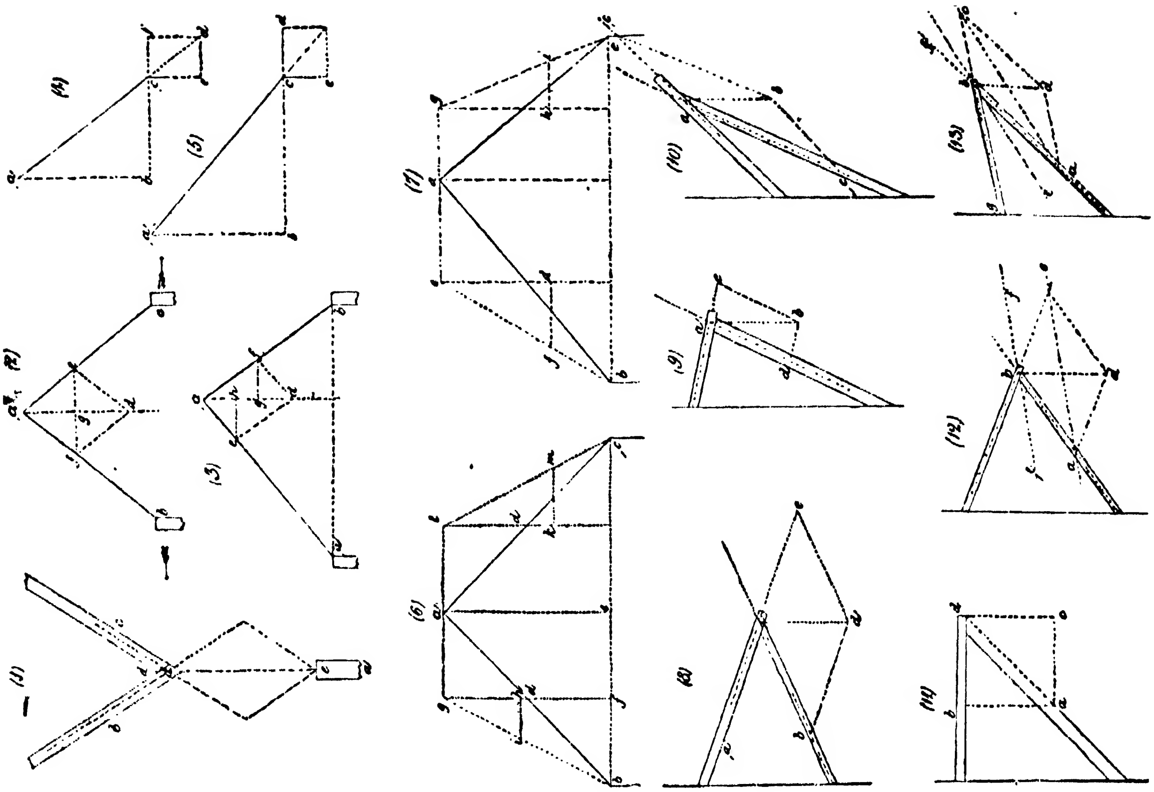
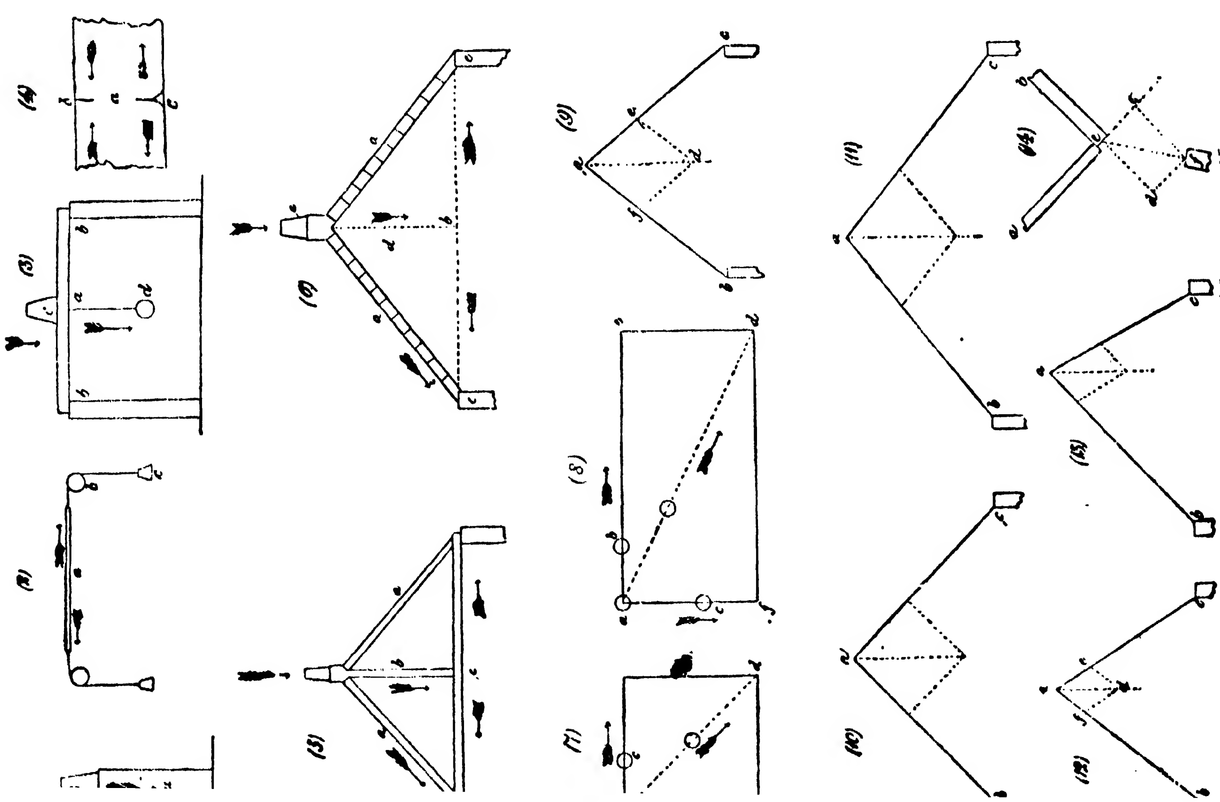


FIG. 8.





THE TECHNICAL STUDENT'S INTRODUCTION TO THE GENERAL PRINCIPLES OF MECHANICS.

LAWS AFFECTING NATURAL PHENOMENA—MATTER AND MOTION.

CHAPTER XXXIV.

Matter.—Bodies.—Materials.

WE said under this head, at the end of preceding chapter, that the mechanic has frequently to change the character of the materials with which he has to deal, to fit them for his work; or failing this work as done by him, the man of science for him is, so to say, compelled to find out methods of working or preparing those materials. So that what appear to the unthinking mind to be simply difficulties thrown in the way, preventing man from availing himself of natural products, are seen by the reflective mind to be some of the kindest provisions of an all-wise Creator; inasmuch as, to get the highest and widest range of usefulness out of natural materials man is compelled, so to say, to exercise his power of observation and of thought, and to apply his skill and energy to discover new combinations, invent new processes, and design new machines, appliances, or apparatus. Let the youthful reader, in looking on the one hand at a mass of crude cast iron, or, better still, a mass of iron ore, and on the other the finely delicate hair-spring of a watch, try to bridge over, so to say, the wide interval or space which separates the highly finished product of the spring from the mass of iron ore from which it has been made; and he will see that to fill up that space an enormous amount of thought, inventive ability, and constructive skill must have been expended before a result so surprising and yet so satisfactory could have been obtained from an origin so unpromising. The youthful mechanic will thus perceive that the mere number and variety of the materials and their characteristics compel, as it were, that patient observation and that careful thought which put into action can alone give him the materials in the form and with the characteristics his special work demands. After these preliminary and, as we design them to be, practically suggestive remarks, we proceed to point out some properties of bodies or materials to which we have as yet refrained from referring, or, if we have named them, have done so only incidentally in connection with other points.

Bodies for our specified purposes we prefer to call materials, as they are all made up of "matter," which has been treated of in an early chapter. All the phenomena presented by those materials are, as we have said, regulated and controlled, as they are, so to say, created, by the two great laws of nature—attraction and repulsion. That of attraction is the one which brings about all the conditions to which we have given the names of porosity, density, hardness, elasticity, ductility, malleability, etc., etc. And before beginning to notice specially each of these characteristics of materials, it is here again necessary, as it is interesting, to observe what we have already referred to,—that those characteristics are only relative, not absolute. Thus we take a bar of steel, and find that by no force manually employed can we bend it or cause it to change its form; and before this change can be effected, it requires the application of a higher force. We decide that it has a certain property to which we give the name of rigidity, and are inclined naturally to conclude that rigidity is an absolute property; hence we classify, or attempt to classify, bodies as rigid as contrasted with those which are not rigid. But there is actually no such thing as positive or absolute rigidity, for the same bar popularly pronounced to be positively rigid, under other conditions can be so reduced in rigidity that its form can be changed with comparative ease. So, again, in relation to the property of materials known as porosity, the characteristics of which will be explained in next paragraph, we take a mass of metal, say gold, and in examining it and knowing its "behaviour"—to use a term employed by engineers—under ordinary circumstances we popularly pronounce it to be a non-porous substance. But as there is no such thing as positive or absolute rigidity, there is also no such thing as positive porosity; for under certain conditions the same mass of metal can have water squeezed through its pores. The same holds true of all the other properties of materials to which certain names are attached, as if these properties were positive or absolute. But although those names do not convey scientifically correct conceptions, as the properties are only relative or rather conditional, dependent upon circumstances, still they are highly useful in conveying to the mind certain attributes which belong generally to the materials in what may be called their normal, natural, or ordinary condition. In no department is the truth of the proverb "circumstances alter cases" or conditions so true as in that of materials. And if we find, as we shall do, that the one great law of attraction regulates the properties of bodies—such as porosity, density, etc., etc.—so the other great law, that of repulsion, causes many of those changes in their condition by which we see that these properties are only relative or conditional, and not absolute or positive.

Constituents of Bodies.—Properties of Bodies.

In an early chapter in the present section we explained, as clearly as the natural obscurity of the subject permitted, the nature of the constituents of all materials or bodies, and there showed how those ranged themselves under what may be called three

classes: first, atoms; second, particles or molecules; and third, masses. Rigidly followed out, all bodies are composed of atoms only, this being the primary or elementary form, if this term can be applied to what have never been seen and cannot be divided, as they cannot be handled. The law which regulates the grouping together of atoms so as to form particles or molecules, and of particles so as to form masses, is that of attraction. And it is the way in which this law operates in relation to the atoms and molecules which gives the characteristics of bodies, or what we call materials. In this connection the young student had better confine his thoughts to molecules or particles, those being capable of physical examination—atoms, after all, so far as we are concerned, being but mental conceptions. Let him, therefore, consider a number of molecules possessing the chemical and mechanical features which make up the constituents of any body or material as drawn or massed (see "mass" in a preceding paragraph) together by the law of attraction so as to form a solid body. He will be apt to conclude that this solidity is obtained by the molecules lying so closely together that all their sides touch or their surfaces are in contact with each other. This is not so, for scientific men have discovered that the law of attraction, in massing together the molecules of a material, apparently acts not over all their surfaces, but only at certain of their points, the point of one molecule attracting or being attracted by the corresponding point of another and its neighbour molecule, and it is only those points which attract to or cohere with each other. This peculiarity is illustrated by—if, indeed, it may not hereafter be proved to be the same action as that of—the "behaviour" of magnets, which, when placed in conjunction or closely to one another, attract each other only at certain points, and never at any other. To those points in magnets the name of "poles" has been given. And borrowing the term—if, indeed, as above suggested, it be not strictly applicable, inasmuch as from recent discoveries and applications of the principle which we call electricity it is probable that this is present in all molecules and masses—this peculiar mode of attraction of atoms or of molecules is called the polarity of atoms or of molecules. Now, if the young student will think the matter over, the variety of the constituents of materials which gives the varieties of the materials themselves must give a variety in the form, so to express it (for no other mode of expression is available in our language), of the atoms or molecules. And the forms being different in different constituents or molecules of different materials, the poles, so to say, will be different—so that attraction, acting through these, will give different arrangements of the molecules. Now, we find that each body (and this almost follows as a natural conclusion from the above) has its own molecules, possessed of their own polarity, and which is not possessed by the molecules of any other body. Thus it comes about that each body has its own definite arrangement of molecules, and to this the name of "crystallisation" has been given. Certain mechanical results flow from this property, and on these we may yet give some practical remarks. The crystallisation of cast iron, for example, is so affected or so controlled by the form or shape of the casting that its strength is materially affected—weakened by one form, strengthened by another. Each body or material is now known to have its own peculiar form of crystal or disposition of its molecules or particles; and the investigations into the different forms of crystals or dispositions form a distinct, as it is a most interesting, branch of physical science. We do not here propose to enter any further into the subject of crystallisation, or, as we here, in view of the special purpose of our papers, prefer to call it, the molecular condition of materials. Suffice it to say that, apart from the interest it possesses to the scientific man, demanding, as it does, a knowledge of geometry and the higher mathematics, it has a high value to the mechanic, who is called upon so frequently and extensively to deal with metals known as the "useful" in contradistinction to the "precious" metals, with which constructively he is not concerned, however much he may be interested in accumulating them as the reward of his work. For the fact is that, while we do not as yet know much as to this molecular condition of metals, still we know enough to put it beyond all doubt that further investigations into and discoveries connected with its phenomena, and a more correct view, if one not absolutely complete, of the law which regulates those, will yet be of vast service to the mechanic. And while, in taking a general survey of natural objects as they are presented to us in different parts of the globe, one is surprised at and in many instances overwhelmed with the vastness of nature's manifestations, it is in turning our attention in the other direction, and taking cognisance of the minute in nature, that perhaps the widest field for surprising and unexpected, nay, even startling manifestations, is opened up to the inquiring mind. And in no department is this so strikingly true as in that of the metals with which the mechanic has to deal. In studying the various points connected with the manufacture of iron and steel, the student will have occasion to deal with some of the remarkable points connected with those metals. And none are more striking than the effects produced in their character by causes of the most minute, and what men would be disposed at first sight to call trifling causes. The characteristics of the metals which give them all their value to the mechanic as constructive materials—such

as ductility, malleability, elasticity and the like—are rendered either more or less valuable by the most minute changes in their molecular disposition or condition; and those are brought into existence by substances equally minute. That many points now obscure will yet be made clear we have no doubt; and when this is so, we have every reason to believe, judging from past experience, that we shall then be able to master difficulties which at present conquer us, and shall have the ability to get rid of those defects in steel and iron which at present to a very large extent harass the mechanic in his work, and but too frequently cause failures and losses. And this can only and will only be done by patient investigation, by close observation and closer thought; and while the range of daily work presents a wide field for the exercise of those faculties, the young student should remember that it is or will be equally open to him; and that to him may yet be granted the like honour that has been granted to his predecessors, of being able, as the result of his observation of and thinking about the phenomena of his daily work, to discover, if not the law which regulates all the phenomena of molecular conditions of materials, at least facts which may be of the greatest practical service to the engineer and the machinist. So much that is valuable beyond calculation has been discovered in the past that there is every encouragement for the young student in mechanics to cast in his lot with those who will yet be the discoverers of the future; and in connection with this important subject we have been glancing at there is a field as wide as it is useful open to his observation and research.

Properties of Bodies.—Porosity.

Remembering what has been advanced in the beginning of last paragraph as to the polarity of molecules, by virtue of which apparently the molecules of bodies touch each other at certain points only, the student will be able to perceive that, according to the primary shape of the molecules, there will be vacant spaces left here and there between the points or parts which do not come in contact. This may be explained thus. The student must here note that the connection between the molecules *at* the point or part of contact—that is, the "cohesion" between the molecules—is so perfect that the best idea to be obtained of it is to suppose the two particles to be fused or soldered together so that they form one or a homogeneous mass. Suppose, then, that we represent the molecules as squares, or rather as cubes. If the molecule disposition were such that those cubes touched each other, or came in contact with each other at their sides, a number of them would lie together, and the cohesion being perfect, there would be no spaces between the cubes as at the lines of contact. The contact or cohesion of the cubes being perfect, in point of fact they would form a solid mass, represented by one block. But in virtue of the polarity of atoms or molecules—which, so to say, causes them to prefer a disposition by which one part only is attracted to another part only—we can suppose the cubes touching or cohering at certain points only. This arrangement naturally leaves vacant spaces between the cubes. But in making up a "mass" the molecules represented in our supposed illustration by cubes must be disposed in a succession, so to say, of layers—one set of cubes being superimposed upon another set. But while being of necessity so, the molecular disposition might be such that the vacant spaces in one row might be placed over the solid parts of the row, say immediately below. Viewing the molecules as a mass, it will be obvious that the spaces would be perfectly isolated—being surrounded by solid matter, so that there could be no communication between one space and another. Vertically, therefore, so far as any communication between one space and another was concerned, the aggregation of solid parts and vacant spaces would be the same as if the mass were a perfectly solid block throughout. We thus have a series of continuous channels, placed within the mass of molecules, which extend from top to bottom of the mass or body. The young student will, of course, understand that in giving this illustration we do not wish him to infer that the disposition of molecules is such as we have named: it is entirely a supposed case; and, however little required by advanced students, we give it in order to induce the youthful student to think all points as fully out as he can, while at the same time it serves very clearly to explain a very important property of materials used by the mechanic, the point or rather the principle of which is not always understood, even by those who have been long engaged in mechanical work. The youthful student will also bear in mind that the various materials he works with, being made up of various and varying constituents, as each molecule, of course, possesses its own polarity, the disposition of the molecules will be different in different materials,—which is but another way of repeating what we have already in last paragraph stated, that each body has its own particular crystallisation or molecular disposition. Some materials, therefore, will have comparatively very large channels or passages, and numerously disposed in the mass, while others will have passages very minute and very few in number. This characteristic property of materials, as having channels or passages formed within the mass or body, has its name in the science of physics given to it from the Latin form of the word passage we have just used—this word being *porus*, and this again derived from the Greek word *poros*, which signifies a passage, duct, or channel. Hence our word *Porosity.*

THE CALICO PRINTER.

The Chemistry and Technical Operations of his Trade.

CHAPTER XXII.

THE CHEMISTRY OF THICKENERS.

Their Uses and Qualities.

It is the province of thickeners, as before explained, to enable the colouring-matters to be printed upon cloth with perfect definition of outline, which would not be possible with a thin or watery composition. Various substances are employed as thickeners, each varying more or less in their quantities; some being soft and pliable, for example, others harsh and strongly consistent, but all of them possessing, in greater or less degree, the necessary character of "consistence" or pastiness. For different styles of printing, and of colours, different thickeners are required. As a rule, thickeners should have no chemical action upon the dyestuffs with which they are employed; in some cases, however, as in the case of arsenic and glycerine in aniline colours, the thickener is acted upon, being rendered *thicker* by a kind of coagulation taking place, and then a *less* quantity of the thickener per gallon will be required to give the proper consistence than would be the case in the absence of the active substance. On the other hand, some dyestuff employed may act upon the thickener in reducing its consistence, and then a greater quantity of the thickener per gallon will be required to give the proper consistence than would be the case in the absence of the active agent —as, for instance, when the colour-composition contains a mineral acid.

The substances employed as thickeners are starches, flours, British gums and dextrines, gums, gum-tragacanth, albumen, casein, and glue.

Starch as a Thickener.

There are various kinds of *starch* in use—viz., wheaten, potato, Indian-corn, sago, rice, and tapioca. For printing purposes the first-named is most highly esteemed; for finishing purposes all are employed. Starch is a widely distributed substance occurring in the mass of nearly all vegetables and in many animals. It is contained in little cells in the living plant, and, before it can be employed industrially, the plant has to be torn, so to say, to pieces, and the starch washed out with cold water: the water with the starch-powder in suspension is collected in tanks and allowed to settle; the water is then drawn, and subsequent washing and purifying yields pure white starch. It is composed of separate minute *granules*, which may be distinguished by means of the microscope, forming an exceedingly fine white powder, and the name applied to them is *amylum*, meaning "grain which needs no grinding." The size, form, and markings of the granules of different starches differ, and, by the aid of a powerful microscope, may be distinguished from one another: thus it is easy to detect potato starch when mixed with Indian corn or rice, provided the starch has not been boiled in water, as this breaks the granules and effaces the distinctive markings. Starch is insoluble in cold water, but when boiled with water forms a *paste*, and it is in this form that it finds employment in calico printing and finishing.

The exact temperature at which starch and water expands into a paste, or thickens, varies from 50° C. to 90° C., according to the source from which obtained. When solution of iodine (in iodide of potassium or alcohol) is added to very dilute cold starch paste a beautiful bright colour of "iodide of starch" is produced; on boiling this the blue colour disappears, and on cooling again the blue returns. This characteristic property of starch is employed for its detection in fabrics, etc.

When starch is slightly acted upon by heat or by dilute mineral acids, British gum or dextrine is produced; when the action becomes stronger the dextrine is converted into other products, such as glucose. Long exposure to air decomposes starch paste into lactic acid and other products. Pure starch, when ignited and burned away, leaves only a trace of ash. Its chemical composition is expressed by the formula $C_6H_{10}O_5$.

Properties of Starch.—Starch is hygroscopic—*i.e.*, absorbs water from the atmosphere in considerable quantity; and most of the starches in commerce contain a considerable percentage of water—namely, 5 to 25.

The following are the most important properties of starch, other than those detailed above.

Prolonged boiling of starch with a large amount of water converts it into a modification termed "soluble starch"—a kind of solution taking place, and the addition of a little caustic soda producing a clear liquid. The same action takes place when starch is heated with glacial acetic acid to 100° C., or with glycerol to 190° C. The addition of alcohol to a solution of soluble starch completely precipitates the starch.

Caustic alkali solution, containing about 2 per cent. NaOH or KOH, causes starch to swell up into a strongly consistent paste, which is soluble in water. The addition of caustic soda or potash to ordinary aqueous starch paste—containing say 10 per cent. of starch—renders the paste considerably thicker. Other alkaline bodies have a similar effect: as, for example, borax. Ammonia, however, has no such action on starch.

Tannic acid produces a white precipitate in a cold solution of starch. Lime and baryta water also yield white precipitates with solution of starch.

Flour occurs in large quantity in cereals and

other vegetables; it is composed essentially of starch and *gluten*—the difference in properties between wheaten starch and wheaten flour being due chiefly to this latter constituent. Good wheaten flour contains about 75 parts of starch, 10 of gluten, 10 to 15 of water, ·7 of ash, ·7 of fat, and ·8 of woody fibre, in 100 parts of flour. Gluten, as obtained from flour by kneading some flour in a cotton bag in a stream of water, so as to wash away the starch, is a pale yellow, highly adhesive, elastic material; it differs from starch in the important point of containing *nitrogen*, which is the *nourishing* part of gluten, as contained in flour as an article of food. Gluten is soluble in hot water, forming a paste of a more tenacious nature than starch. When flour paste is exposed to the air it decomposes much sooner than starch, and it rapidly becomes *mouldy*; this is owing to the nitrogen it contains, which is favourable to fungoid growth.

These qualities of gluten readily account for the successful employment of pure starch in some cases and of flour in others.

Dextrine is produced by acting upon starch by heat and by acids—by heating with water up to a temperature of 302° F. (150° C.)—by heating dry up to 392° F. (200° C.)—by boiling starch paste with very dilute sulphuric or nitric or hydrochloric acid and water, and by modifications of these methods. It occurs in commerce under a variety of names and of very varying quality—containing generally from 20 to 50 per cent. of unconverted starch. That called British gum is more or less brown or yellow coloured; that termed white dextrine is generally wholly or nearly wholly converted pure dextrine.

Dextrine, though of exactly the same ultimate composition as starch—being, like it, represented by the equation $C_6H_{10}O_5$—yet differs from it in many important particulars. It is, when pure, a white or pale yellow or brown fine powder, the particles possessing no structure like starch, the granules of the starch being destroyed during the conversion into dextrine. Dextrine is soluble in *cold* water, more soluble in hot water, yielding a solution of much less consistence than an equal weight of starch boiled with water. The solution of dextrine is sweet to the taste; it does not yield a blue but a *brown* compound, with solution of iodine.

Natural Gums are the dried exudations from certain kinds of trees; they are known as gum arabic and gum senegal, but both these varieties are practically nearly the same article—arabic is generally a finer quality of gum than senegal. Gum is readily soluble in water, and largely soluble in or softened by boiling water, forming a thick, viscous, adhesive, smooth paste, which serves as an excellent thickener. The solution in water is precipitated as a white powder by alcohol. In common with starch, gluten and dextrine, gum is decomposed by mineral acids, being converted into a variety of products—chiefly mucic acid. The aqueous solution after a time decomposes and becomes of acid reaction. Gum, when ignited, leaves about 4 per cent. of ash, which consists chiefly of lime. Pure gum has no chemical action upon most delicate dyes, nor on most mordants; it is, however, precipitated by basic acetate of lead, forming a white jelly; and also by borax, potassic silicate, mercury chloride, and ammonium oxalate.

Commercial gum always contains a certain amount of adhering extraneous matter, woody fibre, sand, etc.; this is got rid of by boiling the gum with water and letting the impurities settle in tanks.

Gum tragacanth is, strictly considered, not a gum, and differs very widely from true gums in its properties. It is obtained from the *Astragalus verus* tree, etc. It is white or yellowish, nearly insoluble in cold and hot water, but in both it swells up enormously, yielding a fine, soft, inadhesive paste or mucilage, which is a most useful thickener. It is not a single compound, but consists of about 60 per cent. of a salt of pectic acid, and lesser quantities of soluble gum (about 10 per cent.), starch, and cellulose (5 or 6 per cent.), mineral matter (3 per cent.), and 20 or 25 per cent. of water, besides traces of nitrogeneous matter.

Long exposure to the air affects its decomposition into acid products.

Albumen occurs in a great variety of animal and vegetable products, but commercially it is always obtained from the serum of blood and the white of birds'-eggs. It is a very different substance from any of the above-treated materials used as thickeners. It contains, besides carbon, hydrogen and oxygen, nitrogen and sulphur, and a small quantity of soda; hence solutions of albumen quickly yield to fungoid growth. Albumen is soluble in cold water; when this solution is heated to about 75° C., or when a mineral acid is added the albumen is completely precipitated or coagulated as a white substance having the same composition as soluble albumen, except a slight difference in the amount of alkali (soda). When this precipitate is collected, washed and dried, a hard, white, horny substance is obtained, which readily absorbs moisture from the atmosphere; it also has gained the property of combining with many dyes, such as magenta, forming insoluble lakes, and hence the application of albumen in fixing aniline colours. Coagulated albumen is soluble in ammonia and in soda. Albumen is coagulated by all mineral and many organic acids, but not by acetic acid; many metallic salts also produce coagulation, such as alum, sulphate of copper, and nitrate of lead; tannic acid, aniline and carbolic acid produce a like result. Albumen combines with lime, forming an insoluble salt.

THE GRAZIER AND CATTLE BREEDER AND FEEDER.

THE TECHNICAL POINTS CONNECTED WITH THE VARIETIES OR BREEDS OF CATTLE—THEIR BREEDING, REARING, FEEDING, AND GENERAL MANAGEMENT FOR THE PRODUCTION OF BUTCHERS' MEAT AND OF DAIRY PRODUCE.

CHAPTER XXVII.

Grazing a Complicated Art, requiring great Knowledge and Skill on the part of the Grazier.

WE have thus attempted to show how complicated a matter the art of the grazier is, and how far removed it is from that condition of such extreme simplicity that any one can manage its details, which is the opinion held by so many. We see that it is more than an art, it is a science—as indeed the most of our arts are—demanding a much wider knowledge than is supposed, and opening a very wide field for accurate observation. But there are still several details yet to be noticed in connection with the practical management of the pasture fields of the grazing farm. These details refer chiefly to the class of cattle which are to be depastured so as to make the most of the food at disposal of the grazier by getting his cattle fattened in the quickest way. We are here supposing that the grazier is confining his attention to this class of stock—that is, that his farm is what is called a cattle or bullock-grazing farm, in contradistinction to that termed a sheep-grazing one. By the first named of these two classes it is not meant that they are fitted only or exclusively for cattle fattening, or for breeding, rearing, and preparing stock for the butcher. Dairy-cow feeding is also included in the class, and it is frequently a difficult matter for the grazier to decide whether his lands will suit dairy cows or fattening cattle best. One at first sight would suppose that, both being in the broadest sense of the term cattle, what would suit one would suit the other; but so far is this from being the case that many of our readers will be surprised to learn that the majority of grazing lands or pasture fields are not adapted to give the best, many not even able to give moderately good results, for both classes of cattle, or specially for dairy cows. No doubt it would seem, judging from the actual practice of the country, that this was not true; but perhaps the best proof of its accuracy is the fact that so many dairymen complain that dairy-cow produce does not pay; and the returns of the average farms certainly show yields far below that which they ought to be if the lands were the best suitable for dairying. The matter for surprise, indeed, is, how dairy farmers contrive to make both ends meet at all, when one considers the kind of lands they have to feed upon and the way in which they generally manage. No doubt whatever exists in the minds of those who really know the conditions on which dairy farming should be conducted, but know that, with a different cultural management of their lands under grass—that is, natural pasture—and a more carefully thought-out system of culture of crops adapted to soiling or house feeding, dairy farms at present yielding at the best but a produce which barely pays would be fairly if not largely productive.

Fatting Stock with Artificial Food.

What remains to be further said on the subject of dairy and grazing management may, if space permits, yet be given; but we pass on to the details yet to be noticed in connection with the grazing of fattening cattle. In feeding cattle off pastures the same principle which guides the cattle breeder when he stall- or yard-feeds with artificial food, as oil cake and the like, the grazier must ever bear in mind, if he desires to be successful in fattening his stock quickly and economically. This principle is that fattening must be steadily progressive—that is, that improvement goes on from period to period, from the time at which it is begun till that at which it is finished. Any "backening," that is, falling off in condition, is from every point of view greatly to be regretted, and all means, therefore, should be adopted to prevent it. For, although it may at first sight appear to be no necessary or, indeed, likely result, yet it nevertheless is just that which comes about,—that if an animal when being fattened is from neglect of any kind allowed to go back or fall off in condition, it not only takes a long time to bring it up to good condition, but in many cases the same point is never reached, so that no after treatment, however good, will give the animal the finished condition which it would otherwise have had. Hence the necessity to look carefully after the pastures to see that the full bite necessary is obtained; and—what is the point so often overlooked, and that, moreover, which affects the point we have now been considering—that this full or necessary feed be kept up. This will not be the case if too many animals are put in one field; and especially where they are unequal—that is, old and young mixed—for in this case the feed will be soon done, so far as the full bite is concerned; and in their desire to have the best the field affords, the stronger animals are certain to drive off from eating the younger and weaker ones. These untoward results may be prevented by the system of field management in classes we have already explained—and further, by taking care to have the fields not too large or too many cattle put into them. As regards the latter, we should be inclined to put the maximum at fourteen or fifteen, never in any case exceeding twenty or twenty-one acres, while in any farm they are much below those extents. At the same time every attention should be given daily—and many a time

a day for the matter of that—to see how the animals thus allotted "behave" themselves. We cannot too strongly impress upon the young grazier the imperative importance of making his animals a matter of individual study, in order to gain a knowledge of their peculiarities and fattening capabilities—the latter, indeed, being, as a rule, dependent upon the former. Every successful breeder has been noted for his intimate knowledge of the animals by which he has gained his reputation, and by which he has so helped to increase the value of our breeding stock.

Extent of Land given to Stock.—Purchasing of Stock.

The extent of land given to or rather required by a bullock or full-sized dairy cow will vary, of course, according to the goodness of the land and the fulness of the bite. But the average may be taken at from an acre to an acre and a half. With the soiling system a bullock may be fattened or a dairy cow fed upon a much less extent of land than this. On good average land a sheep may be fed in addition to the bullock. And it is here that the value of the points we have already detailed as to change of pastures and the gradual bringing of cattle from the poor up to the best pasture comes in. It is not easy to overrate the value of the system of changing the pastures in a fatting point of view. The methods of purchasing stock for fattening and dealing with them on the grazing farm varies with circumstances and often with the locality. Many—it might be said the majority—purchase their stock, and this in a general or open market. Others—and these may be said to constitute the aristocracy of the trade—breed and rear their own stock; and it requires scarcely to be noted that it is to these that we owe all our improvements in cattle breeding and feeding, giving us those herds which have placed our cattle and dairy cows at the head of all the breeds of the world. In buying in open market, however skilful the grazier may be in judging of a good fattening beast, he runs risks which no skill can provide for or judgment foresee, and which, as a rule, the home breeder avoids. On the purchasing system, lean and young or store cattle bought in the early spring, as in March or April, are put up in the poor pastures—as in the field system we have already described—and if they are well managed, and have been judiciously chosen for good or fairly average fattening qualities, they may be expected to be in very good condition in the "back end" of the same year—that is, towards or in November. Cattle may also be purchased in the early autumn months, when there is fair feeding to be had in the after grass of meadow fields — which will pay better than taking off a second crop of hay from them—and by carrying on the "field system" we have described, these will be in good condition in the autumn of the following year. In another system store cattle may be purchased at all times of the year; and being thus brought on the farm, are also fattened and sold off in succession. The most advanced system is to buy cattle at the early part of the year, give them green feeding up to the autumn, then finish them off by shed, box, or stall feeding in the winter with artificial food, of which oil cake is the principal substance. As a rule the cattle sent into the market from our great grazing districts as fat are not in reality so, being, in fact, only partially or so insufficiently fed that by a better system, such as that noted here, an additional weight of a few stones may be easily given to them.

Breed of the Animal to be considered in relation to Grazing Land.

In the last chapters we gave what may be taken as a fairly full or exhaustive detail of the various points connected with the management of grazing fields or of pasture land, and comprising to a large extent that of grazing stock. Many points, however, connected with the animals have yet to be noticed, and these will come up for consideration when we take up the management of the year throughout; meanwhile we have here to glance at the kind or class of fattening stock best adapted for the purposes of the grazier. Of the popular fallacies—for there are, as we have seen, more than one—in connection with the art of grazing, that which maintains that grass land will suit any kind or class of beasts the grazier has or chooses to put on it is productive of as much, perhaps of more evil in practice than that other fallacy, that all that is needed for grazing purposes is grass land—that is, that one kind of grass is just as good as another. As grass lands in reality differ in feeding value most materially, as we have shown, so it would be equally easy to bring forward proofs that differing lands require different classes or kinds of animals in order to get the fullest advantage of what feeding capabilities they possess. So far is it from being true that any grass land will suit any fattening ox, that the very converse of this is the fact; for grazing land which will suit an animal of a certain breed will be so poor for another breed that it will in effect starve—that is, make no fattening progress whatever. It is obvious that the poor grasses, or comparatively poor, of land which would suffice to feed and fatten an ox of a small or mongrel breed—as far as an animal of this kind can be fattened—would be quite insufficient for even the feeding, to say nothing of the fattening, of the large-sized, full-boned-and-fleshed frame of a Shorthorn ox or one of the Hereford breed. And in this connection, and as showing how varied are the points in the art of grazing, it is a curious and suggestive theory to

note here, that if a poor or lean store ox were put into the rich, full-bite pasture which would be best for a fattening Shorthorn or Hereford ox, the poor ox would be injured, or at least he would run a great danger of being so, by being fed off the too rich and, for his condition and position, too highly nutritious food.

But not only is it necessary to select with judgment the class or breed of fattening cattle fitted for the land held in possession by the grazier; it is also necessary to attend to the kind of animal in that breed. What are known as oxen—that is, male animals not kept as bulls, and females known as spayed heifers—that is, incapable of bearing young, are in all classes or breeds the best animals for fattening purposes. And from what is here said as to spayed heifers, one would naturally conclude that cows naturally barren—known technically as "free martens"—would be good fattening animals. This is not the case, however, for barren cows never fatten kindly or fully; and the same may be said of very old cows, or cows "dried" off—that is, which have ceased to give milk. In the latter case the best plan is to feed the dairy cow so judiciously during her milking period, that when she is dried off she will be in "goodish" condition for the butcher; so that comparatively little will have to be done in the way of fattening and finishing her off for this purpose. As regards the different breeds of cattle fit for the purpose of the grazier who is fattening animals for the butcher, a few notes will here be useful.

The fattening breed of oxen *par excellence* is the "Shorthorn," at one time known with us, as it is still almost universally known to the Continental agriculturist, as the "Durham," and this from the county of England in which the breed originated. At this point we refer the reader to the historical notes on this "the king of all cattle," as the "Shorthorn" has by some enthusiastic admirers of the breed been called, given in preceding paragraphs. It does not come within the scope of this part of our paper to give more than a mere general outline of the characteristics of the breed from the point of view of a grazier, who is interested chiefly, as a rule, with fattening cattle for the butcher. The "Shorthorn" ox is, as we have said, the animal *par excellence* that is best adapted for the purposes of the grazier; as it may be said to combine all the qualities necessary to give the highest product of marketable value for the least expenditure of food and of the grazier's care. In its frame, or what may be called its "build," it gives all the peculiarities which we have in a preceding chapter described as essential in a quickly fattening animal. Its fore-quarters are deep and wide, giving a full girth, the ribs have an unusual width, spread or curve, while the whole frame has the square and level lines which denote a good fattening animal. The bulk to which the "Shorthorn" can be bred is another feature of the breed; and, what is of great importance to the grazier, this bulk is attained with the minimum of time and cost, as there are none of the breeds at his disposal which takes on flesh so kindly as the "Shorthorn," or arrives at maturity so quickly. The colours of the "Shorthorn" are chiefly red and white, or a mixture of both in a wide variety of styles. The red is rich in tone, and the white clear and pure. Entirely white animals are by no means rare; indeed, some of the best breeding animals have been pure or solely white. Some, however, object to animals having this peculiarity of a single colour of white, but on what grounds it is difficult to name. One point, though, seems to be so generally insisted upon in connection with a purely white animal, that it would appear to be based upon the results of a wide and a well-marked experience; and this is, that if the animal be wholly white, it is essential that it should have its nose pure black—a white animal with a red nose being at once and nearly by all set aside as faulty. This peculiarity in white animals is not confined to the "Shorthorn" breed alone, but it is applied as a test to other breeds. In fattening animals for the butcher the great aim of the grazier is to have the flesh laid uniformly on the frame, so that each part, when cut up for sale, shall have its proper proportion of meat. Some animals of mongrel breed will show a tendency to lay on meat at one part, and so markedly that other points are, so to say, quite neglected. This lumpy, uneven characteristic is absent in good "Shorthorn" animals. The breed has a remarkable tendency to lay its meat uniformly all over the frame,—hence its fine, even outline, which gives the appearance of a uniform frame, illustrated in an early drawing in this paper. This tendency to a lumpy laying on of flesh is, however, not confined to mongrel or coarse-bred cattle, but is often a characteristic of what are really well- or fairly well-bred animals of breeds other than the "Shorthorn," and even of some of this special breed. But the special characteristic of the "Shorthorn" in this respect is as we have stated. Hence its great value as a fattening ox. The legs of the "Shorthorn" should be short, and the frame well set on them, or square, as the term is. A neat, well-finished hind-quarter is indispensable as a good point, which must not be overlooked by the grazier in his choice of a fattening "Shorthorn." An ox with an ill-turned quarter will not give good results. The same may be said of an animal which has its tail so badly set-on that it does not come well out to form the proper and desired square form at the twist. The hind-legs should be nearly straight, and set well under the frame: if the hocks are bent, or too long, and pro-

ject, as it were, from the frame, these are signs of weakness. The front legs, or fore-arms as they are technically termed, should, where they join the frame, be broad, and tapering with a fine bone below the knee joint. The shoulders must be well laid, gently fitting into or mellowing with the fore-quarters. The neck vein should be full and prominent, and well filled in with flesh. The girth of the animal over the region of the heart should be full, and the ribs should spring clear and level with the backbone, this level feature being well developed as they approach the point of the back rib. There should be no depressions or scooped-out-looking parts at this point—the false rib—but the frame should go straight out from the back rib over the hip, giving a gradual, easy taper on the side bones of the tail, thus avoiding the ugly-looking protuberances and correspondingly ill-looking hollows which are but too often seen in ill-bred animals.

The "Hereford" breed is so distinguished as a fine one that it may be said to form the class next in rank to the Shorthorn. By many it is preferred to the latter breed; being characterised by many fine qualities as a fattening animal for the grazier, and as giving rich and juicy meat to the butcher. The general appearance of the Hereford ox is not much unlike that of the Shorthorn, although the breed is what is called a middle-horned one. The well-filled-in square-like frame is a characteristic of the Hereford equally with that of the Shorthorn; while as ready and kindly layers-on of flesh or meat—in other words, as economical fattening oxen—many prefer them to, or at least esteem them equally with, the Shorthorn. As we have said, the quality of the meat is fine: not hard, but juicy, and fat and lean well intermixed; there is but a small proportion of the coarser parts of meat, the bone and the offal very small in proportion to the bulk of the animal. Taking it altogether, the Hereford fattening ox is at least very nearly equal to the Shorthorn in value, and may be looked upon as superior to any other breed after that. As a breed for dairy cows, it is not held in high esteem; and it is worthy of note in this connection that a remarkable peculiarity of the breed is the great disproportion between the size of the dairy cows and the oxen—the latter being of large bulk, while the Hereford dairy cow is smaller, much lighter fleshed, and altogether a fine and delicate animal. The general or ordinary colour of the Hereford ox is a brownish red or reddish brown; the white face or muzzle and the white tip of the tail are marked general characteristics of the breed; but the white is generally developed also on the mane, the throat, and the inner and lower parts of the legs. Altogether the Hereford ox is a fine-looking animal, and is a marked feature of the shows held in England. The "points" constituting a good animal are very similar in general character to those of the Shorthorn—or, indeed, of all breeds fitted for the grazier—and which we have in an early chapter, while treating of the principles of breeding, gone somewhat fully into.

The "Devon" breed should properly have had precedence of the Hereford, as the latter may be said to be but a variety of the Devon. One feature which gives the Devon its high value to the grazier is that its hardy characteristics enable it to adapt itself to such a wide variety of pastures and localities that it can be fed and fattened in districts and under circumstances which would not be esteemed favourable either for the Shorthorn or the Hereford, both of which require the richest and best pastures to have full justice done to them. A Devon will, indeed, thrive where a Shorthorn and a Hereford would but barely exist. This valuable peculiarity in the Devon partly arises from its physical conformation and habits. It is of small size or bulk, quite distinct from the ponderous bulk of the Shorthorn or the Hereford; all the animals have a light, elastic elegance of movement which enables them to get over ground, and find food over a wide extent of pasture, so poor, or comparatively poor, that a bulky Shorthorn or Hereford would wear itself out, in other words expend its force uselessly, in seeking for food. It is this very characteristic of the Devon breed which makes it so valuable to the grazier, for it can use up pastures in districts in which pastures are comparatively poor, and withstand climatic changes in temperature and the like without injury; or at least without being injured to anything like the same extent as would be the Shorthorn or the Hereford—to which, indeed, similar circumstances of pasture ground would be in practice simply inimical to or destructive of all fattening progress. But this is not the only characteristic which makes the Devon breed of oxen peculiarly the graziers' breed. For while they can and do thrive under circumstances not suited to the Shorthorn or the Hereford, they turn the poor or comparatively poor pastures they feed upon into meat of quality so good that it takes as high a place in the estimation of the butcher as the meat of any other breed, not excepting that of the Hereford, which always holds a high position as butchers' meat. But not only is the quality of the flesh of the Devon ox good, but it lays it on its frame kindly, and so quickly that when it has really good pasture to feed upon it matures faster than any other breed. While, therefore, it has a capability to adapt itself to a wide range of climatic and feeding circumstances, and a ready capacity to give good meat and to lay its flesh quickly and kindly on, we need not be surprised at finding an authority calling it a "first-class graziers' and butchers' beast."

THE BRICKLAYER OR BRICKSETTER.

THE PRINCIPLES AND PRACTICAL DETAILS OF HIS WORK.

CHAPTER XVII.

Ornamental Brickwork (*continued*).

AT conclusion of preceding chapter we alluded to the fact that of late years many forms of decorated and decorative bricks have been introduced. In Plate X. we give diagrams showing different forms of bricks with ornamental profiles and surfaces. In fig. 1, Plate X., we illustrate at *a* in section an ornamental brick for the reveal of a window. This is not carried up throughout the whole length of the reveal, but is finished off near top and bottom after the manner of a "stop chamfer" (see papers "The Joiner" and "The Stone Mason"). Other forms of ornamental bricks are shown in same plate.

But while decorated or ornamented construction can be obtained in brick, giving effects in projecting parts by one or other of the methods presently to be illustrated, ornamental effect, in this country at least, is generally attempted to be obtained in modern work chiefly by surface decoration. This is obtained by a process which may be called a modification of mosaic or inlaying work; bricks of different colour being let in here and there, in accordance with a prearranged design, so as to form a pattern more or less complicated or simple, and the colour or colours of which contrast with, or stand out, so to say, from the general surface, which is of course built in brick of uniform colour and quality. There is still another decorative or ornamental effect produced in brickwork, and which is produced by a method akin to the perforated work in stone of the Gothic architects and builders or of metal workers and wood carvers. In this, holes or apertures are formed in the general surface of the wall by leaving out bricks here and there, and this in accordance with a general plan or design, which is so arranged that the holes considered as a complete series form a pattern. These three methods comprise the different classes or styles of ornamented or ornamental brickwork, and of these we now propose to give sundry illustrations.

Coloured Bricks.

We begin with what is essentially the simplest method, in so far that its effects can be obtained by the use of the ordinary or common bricks used in all structures—that is, no bricks of distinct form or section require to be specially made for it. Work of this kind naturally divides itself into two subclasses or divisions: first, the employment of ordinary bricks, so that effects more or less decorative or ornamental in character can be obtained in projecting surfaces; second, their employment so as to obtain decorative effect in surface work,—the only thing which requires to be specially done in these ordinary bricks being to give them different colours by the use of different kinds of clay. What the ordinary colours of bricks are, and how obtained, we have in a preceding chapter explained; suffice it here to repeat that white, black, blue, yellow, and red are the colours met with, and these often in different shades.

We take up first the second of these two subclasses of ornamental brickwork obtained by the use of bricks having the ordinary or usual forms and sections and dimensions—namely, that by which decorative effects are produced by surface treatment or by the method which we have said to be akin to the mosaic or inlaying art, in which the effect is obtained simply by the disposition of bricks which are different in colour from that of the general surface. The simplest arrangement is the "band" or "strip," and of this the simplest form is the single band, as in fig. 1, Plate LXXX. The colour of the bricks, *a*, *a*, forming this, should be in appropriate or complementary contrast (see the paper entitled "Form and Colour as applied to Decorative Design" for meaning of this term, and for other points connected with colour) to the bricks, as *b b*, *b b*, forming the general surface of the wall. Thus, if *b b* be yellow, the band bricks *a a* may be red, blue, or black; or if the general surface be red, the bricks *a a* may be yellow, white, blue, or black. The bands may either be single (as in fig. 1, Plate LXXX.), or double, each row or course being of a different colour. We have seen an arrangement of five rows, as in fig. 2, Plate LXXX., which looked very effective; in this *a a* are black bricks, *b b* blue, and *c c* yellow. In fig. 3, Plate LXXX., we give another of the same kind, in which the bricks marked *a a* and *b b* are black, *c c* and *d d* dark or bright red, and *e e* yellow, the general surface being of reddish or light-red bricks. When we come to illustrate coloured brick arrangements in projecting parts, other examples of the band or strip arrangement will be given.

Coloured bricks in this inlaying system are frequently arranged so as to form patterns showing on the general ground or surface of the wall in various dispositions, which in many cases are very effective, and tend to relieve the uniformity of large surfaces of one colour only, and that but too frequently of a dead, dull character. The combinations of bricks under this system are numerous, as may well be supposed; it may be said, indeed, that practically there is no end to combinations of this kind. In fig. 6, Plate LXXX., a very simple disposition of black bricks in alternate and corresponding positions gives a symmetrical arrangement which contrasts with the general ground of yellow bricks, *b b*; and it is perhaps more effective if these two broken bands or straps *a a*, as they may be called, are covered or topped by a continuous band of black bricks, *c c*. In

this arrangement the upper band, *c c*, should be of a deeper tint than the lower black bricks in the broken band *a a*, as these latter might be dark blue.

Another arrangement of coloured bricks, as in fig. 3, Plate XXX., gives a series of crosses, the bricks of which are a contrast to the general ground or surface. If the latter be red, the cross bricks, *a a*, may be yellow, or blue, or black; if the ground be yellow, the crosses may be red. This forms another example of what may be called a broken or interrupted band or strip. But by arranging the crosses alternately, as in fig. 3, Plate XXX., continuing them along the line decided on, two broken rows may be obtained, the pattern being simply a repeat. Or in place of having this arranged in lines or bands, the disposition as in fig. 1 may be used as a single pattern, repeated at intervals in the surface of the wall according to the taste of the builder. On this as a separate or isolated pattern the bricks may be arranged, as shown, where the third cross is below the two crosses; or it may be reversed; in both cases the cross *a* or *a'*, fig. 3, is placed centrally between *b b* and *b' b'*. The combination of those two diagrams in fig. 3, Plate XXX., gives the pattern or arrangement illustrated in fig. 1, same Plate. A series of this pattern may be carried along the surface of a wall on the same level, forming a species of broken band; and the pattern may be separated at intervals by the interposition of a single cross, or by two crosses, as in fig. 2, Plate XXX.

Fig. 5, Plate LXXX., shows a modification of the cross in fig. 1, Plate XXX. This may be used in line—that is, as a broken single band—or by arranging them as in fig. 3, Plate XXX., it may form two broken bands. Arranged as in diagram A or B in fig. 3, Plate XXX., the pattern may be used as an isolated one, separated by intervals of the ordinary and general surface of the wall. Or by adopting the arrangement indicated in fig. 1, Plate XXX., the isolated pattern may be obtained as in fig. 4, Plate LXXX., and the intervals between this may have at the centre point of each interval a single pattern of the same kind, as at *a a* or *b b*. But in place of having this to run horizontally, it will look better and give greater diversity by placing it vertically—the point *c* being the top, and *d* the lower end of the pattern.

Figs. 5, 6, Plate XXX., figs. 1, 2, 3, Plate CV., and fig. 5, Plate CLIV. inclusive, show other arrangements of coloured brickwork in the same class. In fig. 6, Plate XXX., the upper courses *a a*, *b b*, and two lower courses corresponding in position, are of black brick, the parts *c d*, *e e* in blue, and the central parts, as *f g h i j k l m n o p* and *q* formed by the juxtaposition of the parts of which *c d e* is one of yellow bricks, the general surface being red brick. In fig. 3, Plate CV., the bricks marked 1 2 3 4 are red, 5 6 7 8 white, 9 9 blue, 10 10 black; the general surface being yellow.

Figs. 4, 5, 7, Plate XXX., and fig. 4, Plate CLXXXI., are illustrations in the same class adapted for panel work.

The majority of those styles will be used chiefly for the breaking up of large flat surfaces of brickwork; but how, and in what combination of colours, will depend, of course, upon the builder, and this will show what is called his good or bad taste. In some cases the band arrangements are adopted as string courses, and as forming part of cornices. We now illustrate arrangements of coloured bricks in the class at present under consideration—namely, what we have called a modification of the mosaic or inlaying method of treating materials—those arrangements being adapted to special and distinct parts of buildings, such as quoins, window and door-dressings. Fig. 5, Plate CLXXXI., shows an arrangement for the quoin or corner of a wall, with "longs" and "shorts," *a c*, *b d*, in red brick with "splayed" edges at *e* and *f*; *g* is part of a single band (see *a a* in fig. 1, Plate LXXX.), *b b* part of the general surface in yellow bricks. Fig. 6, Plate LVI., illustrates an arrangement for coloured bricks as a window dressing. If the general surface is in red brick, the parts shaded in dark may be either blue or black or yellow. If the latter be the colour of the general surface, the dark-shaded bricks may be bright red, or blue.

Arrangements of coloured bricks in the same class for arched openings are illustrated in fig. 6, Plate CLIV., figs. 1 and 5, Plate LVI. In diagram A, which is a semicircular arch, the bricks *a* and *d* are white, and *b* and *c* bright red; these are placed alternately, the quoin bricks at the reveal, or "longs" and "shorts," are blue at *e* (shorts) and bright red. The general surface is bright red. The diagram shows an arrangement for a pointed arch, in which the bricks marked 1 2 3 are white, 4 5 bright red, 6 7 black, 8 9 10 are red and black alternately, 12 13 red, 14 white alternately, as "longs" and "shorts." In fig. 5, Plate LVI., which is a semicircular arch—half only, on right-hand side of centre line 1 2, being given—the key stone *a a* is of stone, yellow freestone or blue limestone; *b c* is an outer ring of headers in yellow brick, *d d* half brick "closers" in blue or black, *e e* full length brick "closers" in yellow, *g* and *h* half bricks in blue or black, *i i* whole bricks in blue or black, *f f* yellow, *f' f'* half bricks yellow, general surface in yellow or light red. In fig. 1, Plate LVI., we give two arrangements for arched openings, the shaded portions being in yellow with general surface light red; or with general surface in yellow the shaded portion may be in blue or black—or these may be used with a general surface of red.

THE ROAD MAKER.

HIS WORK IN THE LAYING OUT OF ROADS IN RURAL, SUBURBAN AND TOWN DISTRICTS, THEIR CONSTRUCTION, REPAIR, AND IN THE CHOICE AND USE OF THE VARIOUS MATERIALS EMPLOYED.

CHAPTER XII.

IN last paragraph of the preceding chapter we opened up the subject of the mechanical condition of the roads, as affecting the traction of vehicles running on them; in continuation we have to remark that not less important than the construction of a road is its condition as to cleanness and state of repair in the force of traction required upon it; and the usual modes of construction having, in the foregoing pages, been treated of in considerable detail, the topic indicated above will be a necessary sequel to what has gone before in our paper on "Road Making."

The experiments of Mr. Bevan, given in a tabulated form below, are generally considered to be most authentic on the matter to which they relate; and that is the force of traction required on roads, under different circumstances of construction and condition, to produce and maintain motion in carriages weighing 1000 lb., on a level road.

Description of road.	Force of traction per 1000 lb. lb.
Turnpike road, hard and dry	30½
Ditto dirty	39
Hard compact loam	53
Ordinary by-road	106
Turnpike road, newly gravelled	143
Loose sandy road	204

In the foregoing statement the comparison to be made is rather the force of traction due to different conditions of roads than that due to their construction.

The increase of the force of traction required on the same road in a wet and dirty condition upon it in a clean and dry condition is no less than 28½ per cent.; hence the disadvantage of the dirty road to the clean, and the importance of avoiding any condition by which the materials of a road may be reduced to a state of mud. In this the impropriety of applying any matter, even clean sand, to the surface of a road on pretence of binding, is forcibly shown. On a road without any covering the increase of the force of traction required is nearly 75 per cent. compared with a turnpike road in a hard and dry state. On a by-road, in its ordinary dirty state and imperfect repair, the force of traction required is more than three times that required on a clean turnpike in good repair. On a newly gravelled turnpike the force of traction required is more than four times that required on a turnpike in its consolidated state; and on a loose sandy road the force of traction is nearly seven times that required upon a good turnpike.

From the facts shown in the foregoing table it wil readily be perceived how great is the amount of the force of traction wasted upon roads of bad construction, and the great economy of the same force on well constructed roads in good condition. This naturally brings up for consideration the repairing of roads.

Repairing of Roads.

The efficient repairing of roads is a matter of the greatest importance, and it should always be done in the best possible manner, and should never be slurred over in a mere makeshift way to meet the exigencies of the moment. Notwithstanding the importance of this point, roads are very rarely repaired in the best manner, the matter being generally left to men perfectly ignorant of the right principles of the construction of roads; and by the want of efficiency and thorough repairing of roads much expense, both in the cost of materials and in labour, is wasted to the owners and occupiers of landed property, on whom the cost of repairing roads falls. The steam roller gives now important help in keeping road surfaces in the highest state of efficiency. We may, should space permit, hereafter see how certain modifications in the ordinary method of road construction, recently introduced into practice, have the effect of giving a surface nearly approaching the "standard of perfection"; and how, also, the nature of the materials employed to give the final or permanent surface of the road exercises an important influence on the tractive force required to drag or pull vehicles over it.

Ruts in roads are produced by two different and distinct causes: one being the gradual wear of the covering material by the traffic following the same track; and the other being the displacement of the material by the wheels of carriages and feet of horses before its having become consolidated, in a newly made or newly repaired road. In the first-mentioned case the ruts are comparatively wide and shallow; while in the latter-mentioned they are narrow, not wider than the breadth of a wheel, and deeper than in the first-mentioned case. Ruts, from whatever cause, serve as a lodgment for water, to the speedy destruction of roads, if not carefully filled up with small and clean-broken stone as soon as ever the wound in the surface of the road is discovered.

The best seasons for general repairs of roads are April and May in spring, and October and November in autumn; but any casual injury to a road should always have attention, and the repair never delayed an hour that can possibly be avoided.

The following directions for the repairs of roads are copied from McAdam's own work on "Road Making," published in London by Longman & Co. in

1823; and are equally applicable to any system of road making as to that of McAdam.

"No addition of materials is to be brought upon a road, unless in any part it be found that there is not a quantity of clean stone equal to ten inches in thickness.

"The stone already in the road is to be loosened up and broken, so as no piece shall exceed six ounces in weight.

"The road is then to be laid as flat as possible; a rise of three inches from the centre to the side is sufficient for a road thirty feet wide.

"The stones, when loosened in the road, are to be gathered off by means of a strong, heavy rake, with teeth two and a half inches in length, to the side of the road, and there broken, and on no account are stones to be broken *on* the road.

"When the great stones have been removed, and none left in the road exceeding six ounces, the road is to be put in shape, and a rake employed to smooth the surface, which will at the same time bring to the surface the remaining stone, and will allow the dirt to go down.

"When the road is so prepared, the stone that has been broken by the side of the road is then to be carefully spread on it; this is rather a nice operation, and the future quality of the road will greatly depend upon the manner in which it is performed. The stone must not be laid on in shovelfuls, but scattered over the surface, one shovelful following another, and spreading over a considerable space.

"Only a small space of road should be lifted at once; five men in a gang should be set to lift it *all across*; two men should continue to pick up and rake off the large stones, and to form the road for receiving the broken stone; the other three should break stones—the broken stone to be laid on as soon as the piece of road is prepared to receive it, and then break up another piece; two or three yards at one lift is enough.

"The proportioning of the work among the five men must, of course, be regulated by the nature of the road. When there are very many large stones, the three breakers may not be able to keep pace with the two men employed in lifting and forming; and, when there are few large stones, the contrary may be the case. Of all this the surveyor must judge and direct.

"But, while it is recommended to lift and relay roads which have been made with large stones, or with large stones mixed with clay, chalk, or other mischievous materials, there are many cases in which it would be highly unprofitable to lift and relay a road, even if the materials should have been originally too large.

"When additional stone is wanted on a road that has consolidated by use, the old hardened surface of the road is to be loosened with a pick, in order to make the fresh materials unite with the old.

"Carriages, whatever be the construction of their wheels, will make ruts in a new-made road until it consolidates, however well the materials may be prepared, or however judiciously applied; therefore, a careful person must attend for some time after the road is opened for use, to rake in the track made by wheels.

"The only proper method of breaking stones, both for effect and economy, is by persons *sitting*; the stones are to be placed in small heaps, and women, boys, or old men past hard labour, must sit with small hammers and break them, so as none shall exceed six ounces in weight.

"*The Tools to be used are*:—Strong picks, but short from the handle to the point, for lifting the road.

"Small hammers of about one pound weight in the head, the face the size of a new shilling, well steeled, with a short handle.

"Rakes with wooden heads, ten inches in length, and iron teeth about two and a half inches in length, very strong for raking out the large stones when the road is broken up, and for keeping the road smooth after being relaid, and while it is consolidating.

"Very light, broad-mouthed shovels, to spread the broken stone and to form the road.

"Every road is to be made of broken stone, without mixture of earth, clay, chalk, or any other matter that will imbibe water and be affected with frost; nothing is to be laid on the clean stone on pretence of *binding*; broken stone will combine by its own angles into a smooth solid surface that cannot be affected by vicissitudes of weather, or displaced by the action of wheels, which will pass over it without a jolt, and consequently without injury."

Rules for calculation required in, and data for estimates of costs in road making which have not been previously given in the foregoing chapters.

To find the quantity per yard in length of excavation in forming, or of broken stone or gravel required in covering a road of any given breadth and depth or thickness.—Multiply the breadth of the road in feet by one-fourth of the depth of the excavation, or thickness of the covering in inches, and the product will be the quantity required, in cubic feet. Or—

Multiply the breadth of the road, in feet, by the depth of the excavation, or thickness of the covering in inches. Divide the product by 108, and the quotient will be the quantity required, in cubic yards.

EXAMPLE.—Required the quantity of soil per yard in length that will have to be removed from the site of a road 36 feet in breadth, the depth of the soil being 16 inches.

THE FACTORY OR MILL HAND AS A TECHNICAL WORKER.

THE ORGANISATION, GENERAL DUTIES, AND SPECIAL WORK OF THE STAFF OF FACTORIES FOR THE PRODUCTION OF SPUN AND WOVEN GOODS—THAT IS, "YARN" AND "CLOTH"—AND THOSE CHIEFLY IN COTTON AND WOOL.—GENERAL DESCRIPTION OF THE VARIOUS PROCESSES OF MANUFACTURE.

CHAPTER XVIII.

Operations of the Loom (*continued*).

THE different parts of the loom can be changed, so that different "counts" of yarn, coarser or finer, can be woven on the same loom, giving coarser or finer cloth. The loom has a limit in that direction; nevertheless it must be that a little variation of cloth can be made on the same loom.

It would require a volume of a large size to point out all the minute parts which constitute the power loom, and explain every movement, and the connections of the various actions, so as to enable them to be traced out individually with the other working parts, which must of necessity harmonise in every movement, so that one part can follow another as required: this and only this can constitute a power loom capable of doing the work of a "self-acting loom."

It is always interesting to be acquainted with technical terms—*i.e.*, such as are used in the trade. We shall now give four of the expressions which are common amongst those connected with the weaving of calicoes. Each of the names are used to represent a fault in the weaving—namely, "clouds," "jesps," "gaws," and "scobs." A "cloud" is an expression used to indicate at once its meaning—that is, a thickening of the cloth either throughout its whole breadth, or, as is commonly the case, at the selvage only. A "jesp," on the contrary, is a thinning of the cloth, or rather merely a greater space between two shots or strokes of the lathe than ought to be, at some particular part of the web; whereas a "gaw" is a space continued over the whole breadth of the web, or it may be partially interrupted by a broken shot. A "scob," again, is a blemish in the cloth arising from the interruption of the threads in shedding preventing the proper interlacing of the warp and the weft.

This fault affects both hand- and power-loom goods, but not equally so, as it arises almost wholly from an ill regulation of the hand in working the lathe, to a degree beyond what is to be met with in the trade. It is not to be looked for in work of an average quality.

Clouding and jesping are frequently traceable to the practised eye; and in a great measure arise from the stoppages in working to dress and draw the bore: as in these cases, should the diameter of the beam be unequal, the line of the fell is not straight in commencing again; and where it is concave towards the reed, it will "jesp" and "cloud" where it is convex. The weaver endeavours to prevent these faults by squeezing forward the cloth where the fell is off, and taking out a couple of shots at the selvage in its being forward, as it may require it. But the right remedy is true beams, placed in parallel directions to each other, and light and equal brushing in dressing, so that the yarn may not be unequally stretched, as has been noticed in weaving by hand. But "jesping" may nevertheless take place from unequal strain on the lathe in its attachment to the rocking-tree. In that case the fell, although it may be straight, will be in a somewhat slanting direction, not parallel to the lathe when brought slowly forward, more especially if the weaver works at a great speed. The "jesping" will then be apt to take place at one side only, in commencing again after a stop of any kind, when the lathe has not acquired the full momentum.

But as the power loom is free from the injurious effects on the cloth resulting from the dressing of the yarn in the loom, and likewise from the variations arising from the bore, the cloth is more evenly made than that by hand, although "gaws" are more liable to take place with it than in hand-made goods. But "jesping" may, and does, take place in the power loom, from strain on the lathe in its attachments to the rocking-tree, or from its connection with the crank-shaft, by their not being parallel. There is another cause which is not sufficiently attended to —namely, the vibration of the drum shafts from unequal weakness in working, which very injuriously affects the lathe, in case it should be suffering from any strain in the loom.

The above general remarks may be of great service to those not acquainted with terms used in the process of cloth making. It is more than can be expected of us to give the familiar phrases of the trade for faults in every locality. Those we give are used in the great seats of the cotton trade in the north of England.

Again, the words, "warp," "web," and "chain," are all used as referring to the same thing, but understood in a special sense as applicable to the different stages of manufacture.

The "web" is a general term, and is used in reference to the web in the woven or unwoven state. But the "warp" is specific, and is used as contradistinguishing the one portion of the web from the other, or the warp from the weft. The "chain," again, refers to the warp only as it comes from the warping mill, before it is beamed for weaving.

The "yarn" is the material in a state either for

warp or weft, and a thread is an individual portion of the yarn referred to. The yarn, however, for warp and weft is never mixed, because, as the warp sustains the strain of weaving, it is made of better material, and with more twist than is necessary for the weft.

Weaving.—Parts of a Loom.

We shall now refer to certain parts of the loom. The construction of the power loom had hitherto been based, as closely as possible, on the arrangements of the hand loom. But it was soon found that there was a great difference between the actions of the two mechanical agencies; and changes were early made in the power loom with the view of accommodating it according to its work.

The inverting of the position of the "lathe" was one of the earliest of these changes; and as it improved the machine in compactness of form without being attended with any injurious effect on the motion of the "lathe," as impelled either by the crank or the "wiper" for calico weaving, it became almost universally adopted in the construction of the power loom.

One improvement followed another, and led to a thorough revision of the whole mechanical movements as applied to weaving. These we shall name in the following order:—

First, as to the throwing of the loom out of gear by means of the shuttle protector. Second, as to the motion of the lathe. Third, as to the means for shedding. Fourth, as to the means for picking. Fifth, as to the make of the loom, as best fitted to withstand the reactions of these motions. Sixth, as to the motion for winding the cloth on the beam. Seventh, as to the devising of a means for stopping the loom on the discontinuance or breakage of the weft shot. Eighth, as to the invention of a means to render the temples self-acting, so as to keep the cloth at its proper width at the fell without hand interference, and so save time and save the reed.

Power-Loom Weaving.—Management.

These are important objects, as comprehended in the foregoing heads, since the completeness in the success of the motions of the power loom depends in a great measure on the manner in which they are accomplished by machinery. But the right origination of the means, as well as the appreciation of the fitness of their application, depends on a knowledge of weaving, or those principles of the art which must be inseparably associated with the consideration of the state of machinery as affecting it. Some conception of what must be done to secure good weaving will be obtained by considering the following circumstances connected with the management of the power-loom department of a factory or mill.

A certain number of looms is given into the charge of a man who is known by the name of "tackler." He has the entire control of the looms, and is expected to keep them in perfect working condition. The production of the cloth as to quantity, and even as to quality, will very much depend upon the manner in which he manages the looms and their working.

First, as to the yarn, that it suffer no unnecessary strain in the loom, certain points must be attended to:—(1) as to position—that the warp be in a straight line; (2) as to stretch—that it be of the proper length; (3) as to direction—in the line of the stroke of the lathe; (4) as to support—that it be maintained in the proper line; (5) as to tension—that it be properly paced. *Second*, that the yarn suffer no unnecessary strain from the motions in weaving. To secure this, it is necessary to allude to the following: (1) as to size—that the motions be the smallest that can be rendered sufficient; (2) as to the arrangement as affecting the motions of the shed and lathe—that there be no unnecessary space between the headles or healds and the fell; (3) as affecting the shed—that the shuttle be as thin as may be barely sufficient for a pirn (cop) not inconveniently small; (4) that the size of the shell be barely sufficient to receive the shuttle; (5) that the shuttle line in working be as near the healds as the lathe can be made to permit it; (6) that the lathe be properly constructed for that purpose. *Third*, that the motions as to quality, be good:—(1) as to the lathe—steady and firm in action; (2) as to the shed—steady and easy in motion; (3) as to picking—free and easy in action. Various other matters concern the action of the numerous parts in a power loom to bring all into a state of unison, so that each and every part can operate in turn as required.

We have pointed out many of the most important parts which must be attended to in order that the loom shall be properly prepared for the production of a good quality of cloth. But in addition to the production of a good quality, another point has to be considered,—namely, the quantity of the cloth produced in a given time. Quality and quantity are the two requisites which require every attention, so that they can be obtained. No machine in the cotton spinning and manufacturing process requires more attention to produce those two requisites than the power loom.

Management of a Weaving Factory.

The manager of a weaving factory, who has the charge of the establishment, should be well acquainted with the principles and practice of weaving, and with the capabilities of machinery. But these qualifications are not easily acquired, and are rarely combined in one man. Weaving as an art is seldom thoroughly well exemplified in the trade. The management of the yarn in the loom, so as to effect all that can be

done with it, depends in a high degree on a nice perception of the strain which the yarn is capable of bearing, compared with what it must necessarily suffer in the process of weaving. This talent in discriminating weight is best brought out by practice on the hand loom. But the ability to distinguish with accuracy and precision the difference between the relative forces and the ability to dispose of them to the most advantage, is not commonly met with; and as this ability is necessary to the attainment of eminence in the art, it is not surprising that a *high* degree of skill in the management of yarn should be rarely exemplified in mill practice. And hence the practice, so commonly met with, of working excessive motions; and, as a consequence of their severity on the yarn, a low speed becomes advantageous, as necessary to prevent many breakages in the weaving.

There is a great difference in woven fabrics, beginning at the sailcloth and ending with the finest muslin. Calicoes are a sort of medium between these two extremes. The heavier the cloth which is intended to be made on a loom, the heavier should the loom be. This is the case with nearly all machines, and *vice versâ.*

The speed of a loom (*i.e.* the number of "picks" per minute) is the basis for calculating the productive power of a loom. It will be evident that the wider the loom (*i.e.* the cloth woven in it) the fewer picks per minute will be obtained; the reverse when the loom, or its cloth, is narrow.

That description of goods which is known by the name of "checks" is made of all materials in common use for cloth—as cotton, woollen, linen, silk, or a mixture of them.

The check is formed by having the warp striped in a certain order by warping yarn of different qualities, either as to "grist" (quality), or colour, and crossing these stripes in weaving, at the proper intervals to form the squares with the corresponding kinds of weft.

Checks are therefore woven with a number of shuttles corresponding to the number of colours or kinds of yarn used as weft, to form the pattern when worked along with the warp.

The shuttles must, of course, be changed for this purpose in weaving with them; and this is done by rendering the bob movable, at least at one end of the lathe, and forming it with a separate berth or box for each of the shuttles intended to be used in the work. The movement of the whole box is therefore made in a certain measured manner corresponding to the breadth or depth of each of the separate boxes,—so that any of the shuttles may be brought as required to the plane of the race and the reed, and used till another change becomes necessary. Checks are generally heavy fabrics, about the set of calicoes, especially those made in the localities of Carlisle and Manchester; and therefore no special adaptation of the loom from what has been already described for such work is necessary, except that dependent on the motion for changing the shuttles.

The treadle is worked, so as to raise the boxes successively as the shuttles require to be changed, by the pattern wheel itself, which receives its motion for that purpose from a small pinion on the wiper shaft. This motion of the treadle is effected by the segments screwed to the face of the wheel; and as each segment gives exactly so many shots, according to the pattern, the number of segments in the circle gives the number of changes in the pattern for that shuttle. The next shuttle is brought up by another segment, concentric with the last, and so far within its circle as merely to bring the box which it actuates to the level of the race.

The number of the concentrics of the circles determines the number of the shuttles with which the loom is fitted for working; and the number of segments in each circle determines the changes in each of the shuttles respectively.

In manufacturing by machinery, this operation of "beaming" is entirely avoided, and that of "warping" is much simplified. The yarn in power-loom weaving is taken more directly than in former times, when "beaming" the yarn was a part of the preparation for a beam for the loom. Beaming now is out of date. The yarns (mule cops) as they leave the pinner are wound upon large bobbins, on a cop winding machine. These bobbins are then put into a "creel" of a beam warping machine, capable of taking in about five hundred bobbins. When a certain number of such beams of yarn are full, they are taken to the dressing frame; the number required to give the number of ends to make the beam complete are wound upon one beam as they are being dressed, and hence the necessity of warping, except where dyeing or bleaching is required, and then the species of warping called mill warping must be resorted to.

The fewer changes of fabrics in weaving in one kind of loom the better. There is thus little calculation required in warping for it, and little variety in the operation.

Weaving.—Dressing of the Yarn.

We now come to the operation of "dressing" the yarn to be woven into a fabric. The motions in weaving may be performed in a manner altogether faultless, and the position of the yarn in the loom be the best for sustaining and avoiding strain still there is another consideration connected with the yarn of essential importance to success in weaving (more especially in the fine qualities, both as affecting the quality of the work and the quantity)—namely, the

state in which the yarn is submitted to the loom in the operation of weaving.

Two conditions are included in the state of the yarn. It must be properly "dressed." It must not be impaired by insufficient dressing, so as to bring about that brittleness affecting it in the working. Both of these conditions must be secured to the yarn, so as to fit it for doing what is required. A dry atmosphere is detrimental to the yarn for weaving. Frost is most injurious to it, both in preventing it from taking on the paste used in the "dressing," and especially in rendering the yarn very brittle after being dressed. In hand-loom weaving the ground floor is universally used as the only situation adapted for fine or medium weaving. The ground floor surface is generally the bare earth. In power-loom weaving the ground floor is also made choice of, and this accounts in part, for weaving being carried on in low "sheds."

As to the "dressing room." As heat in the air of the room is not at all injurious to the yarn provided there be a superabundance of moisture with it, the temperature should be such merely as is sufficient to render the place comfortable to the workers.

We may observe here that the object of the mechanical arrangements in dressing is to lay the surface filaments of the yarn in the line of the thread, and secure them in this position effectually by the application of "paste," made of flour, but too frequently of other materials not so "honest," with the least possible waste of the strength of the yarn; and the means will be successful only in so far as they accomplish these objects.

Sizing and dressing of yarns (warps) has been adopted (as far as can be gathered) almost from the earliest times of weaving. It is of the utmost importance that the fibres of the yarn should be so closely fixed to the thread that they cannot be disturbed when in the loom, as the motion of the healds would "fridge" the thread and would so weaken it that to move it would be literally impossible. There is the tape sizing machine and the beam sizing machine. The tape sizing machine is that which sizes the warp as made in the "warping mill"—*i.e.*, in long tapes—as long as are required, which vary in length from two hundred to a thousand yards. The cylinder sizing machine sizes the beam-warping warps or beams. The warps for the sizing on the cylinder principle are run upon beams, and a series of beams are attached to or put up at the machine, and as the threads are drawn off the beam (but at a very slow pace) they pass through rollers or under a roller which is in contact with the "size" or "paste." Simply passing through "size" would not produce the desired effect. Brushes are used so as to wipe off superfluous paste or lumps. The high speed at which the brushes run not only clears off thick or lumpy useless matter (worse than useless, such as would be a detriment to the weaving of the piece), but also performs another part which is as necessary to be done—namely, that of freeing the threads from the over-abundance of "size" or paste, but it lays the loose fibres of the thread so closely to the thread itself, that it appears more like wire than thread when thus sized or dressed for the loom.

The fibres are so well united with the body thread that they are in point of appearance the thread itself. This sizing prevents any part of the process of working in the loom from disturbing the fibres and thus making the cloth weaker and rougher. It will at once suggest itself to the reader that there must be some process for drying the threads after receiving so much damp or wet material as that of the size or "paste." In running the threads upon a beam (which has to be done) they would adhere to each other, and in process of drying while on the beam the threads would be so cemented together that to try to separate them would not only be impossible, but, if possible, would so disturb them that they would be useless for weaving. To avoid this difficulty the dressing or sizing machine is provided with a series of steam chests called steam cylinders. These cylinders receive the steam direct from the steam boilers.

The threads having been cleared from the unnecessary quantity of size by the brushes, and the fibres of the yarn all closely laid in one direction, the yarn then passes but slowly over those large cylinders which are, as we have said, heated with steam.

This machine is provided with a fan, which, as will be at once understood from the position in which it is placed, assists to clear away the steam and consequently the damp which arises from the wet yarn passing over the hot steam cylinders, and thus it is carried away and the drying of the yarn facilitated.

Sizing or Dressing Machines.

The machines employed for the purpose of sizing or dressing are of simple construction. Though simple, they hold a most important position in preparing the warp for withstanding all the strain to which it is subjected in the process of weaving.

In preparing the warp for the power loom the yarn is run into the machine from beams as they come from the beaming mill or beam warping mill, and has thus to be received at the other end on a beam.

The two departments of the process, therefore, of sizing and drying are run together, or rather go on continuously, in the same machine; at the one end the yarn is sized, and at the other dried on the cylinders, and delivered to a beam ready for the weaving room.

THE BUILDING AND THE MACHINE DRAUGHTSMAN.

CHAPTER XXV.

Continuing our description of the projection of a helix or screw, begun in last chapter, we have to remark that when the lines of the windings are thus close together—as in the case of the threads of a screw—the screw is said to have a "slow-running thread," when the lines of the winding are far separated the screw is said to have a "quick-running thread," or the helical line is said to have a "quick turn" or the reverse. The distance between the point where a helical line begins to wind round a cylinder or a line, as at the point *b* in fig. 1, Plate CLXXXII., and the point where it terminates, as at *a*, the line making a complete turn round the whole of circumference, is technically called its "pitch." In the case of a vertical cylinder, this "pitch" may be considered as the "rise" of the helix, in that of a horizontal cylinder its "travel" along the generating body. Fig. 2, Plate CLXXXII., further illustrates what has been said above as to the generation of a point moving along and round a cylinder. In this case the cylinder, as *a b c d*, is supposed to be supported by a shaft *e e*, and to have a motion of revolution given to it in the direction of the curved arrows. A tool *e* or tracing point is kept in close contact with the surface of the cylinder, and the "rest" which holds it has a motion given to it along the length of the cylinder in the direction of the arrow as shown. The speed or travel of this in a given time is in proportion to the circumference of the cylinder *a b c d*, as the thread or winding line *f f* is required to be a quick or a slow turning one. The circular motion of the cylinder *a b c d* is technically termed its "angular motion," in contradistinction to the rectilineal one of the generating point travelling along the length of the cylinder.

The Development of the Surface of a Screw.

In the preceding paragraphs the reader has had explained to him how the surfaces of cylinders and cones can be developed so that they can be made to assume the form of a plane surface: that of a cylinder, for example, takes the form of a rectangle or parallelogram, the height of which is equal to the height of the cylinder and the length equal to its circumference; that of a cone having a form bounded by parts of two circles concentric to each other, terminated and joined at the ends by two straight lines converging, if produced, to a central point, being that at which the sides of the cone, if produced or prolonged, would meet. This principle of development, or the method practised to obtain the development or "stretch-out" of a body, gives us the method of drawing, delineating, or finding the course taken by a helical line, whether that be generated by a point moving round a cylinder or a cone or the frustum of a cone. This we shall now endeavour clearly to explain.

We have seen that a "helical," or, as we may by using the popular term call it, a "screw" line—as the screw is the most familiar exemplification of the helical line in practical work—is very clearly shown by winding a triangular piece of paper, as *a b c*, fig. 6, Plate CLXXXII., round a cylinder or pencil, *d e*. If the reader, on commencing to have the characteristics of screw lines explained to him, has a pencil so wrapped round with a piece of paper presented to him, he might have a difficulty, if asked, to say what would be the shape or form of the paper when unwrapped or unwound from the pencil. But if asked to unwind it, and when he saw the triangle, as *a b c*, he would at once see that this form was in reality the helical line "stretched out" or "developed,"—what had shown at first to be a cylindrical line, gradually going up and round the cylinder, bearing when so stretched out a plane surface. Suppose that he were asked to rewrap or rewind the triangle, as *a b c*, fig. 6, Plate CLXXXII., round the pencil, but before doing so to mark off on the edge *a a* a series of red marks, as 1, 2, 3, 4, on say the blue margin, on wrapping the triangle thus marked round the pencil in the way we have previously described he would perceive that those marks would come in succession in contact with the surface of the cylinder, and occupy certain positions thereon. If the distance between those points or marks was uniform, as that between the points 5, 6, 7, 8, and the whole length of *a c* so equally divided, uniformly spaced marks would be found on the surface of the cylinder. These marks would, on consideration, obviously have a fixed and definite relation to the surface or circumference of the cylinder; and if they could be transferred by some means to the surface of this, when the paper was taken off the cylinder they would be found to be marked by points equidistant round its circumference. Here, then, we should have a combination of two classes of points: first, those on the triangular wrapper *a b c*, and second, those on the surface of the pencil *d e*. Now, if we could exhibit on paper the same number of points, and in the same relationship to each other, we should obviously have a means of delineating on its surface the same helical or screw line as is generated or produced in the manner shown at *f g h i* and *k m n o*, fig. 6, Plate CLXXXII. How to do this is taught us by the principles of the development of surfaces, as explained in preceding paragraphs.

The mode of applying this principle is now to be illustrated.

Three points or data are required to be known in

order to apply this method: first, the projection in elevation of generating body, which in the first instance we presume to be a cylinder; second, its projection in plan; and third, the length of the "pitch," or the distance, as already explained, between the two points, the first at which the helical or screw line begins its winding, and that at which it terminates it on the cylinder. Let *a b c d* in B, fig. 1, Plate CLXXXII., be the elevation of the cylinder — the height of which in this instance is confined to that equal to the "pitch," which is indicated in the length between points *a* and *b*. The "plan" is shown below: the centre *i* of the circle giving this being on the central line *e f* of elevation produced indefinitely below. Divide the circle into any convenient number of equal parts —this being most quickly done by the "T" and set-square—as shown by the points 1, 2, 3, 4, 5, 6, 7 and 8. Divide now the length or height of the "pitch" line *a b* into the same number of equal parts as the plan is divided into, and from those points, as 1, 2, 3, etc., in *a b* draw lines (shown dotted) parallel to the base *b c*. Then from the points in the circumference of the circle or plan in A, draw lines parallel to centre-line *e f*, cutting those drawn from points 1, 2, 3, etc., in elevation. The intersection of the correspondingly numbered lines gives a series of points through which a curved line is to be drawn, and which is that of the helical or screw line required. Thus the intersection of the vertical line drawn from point 1 in plan gives, with the horizontal line drawn from point 1 in elevation, the point *k*, the first point in the curve; the intersection of line from point 2 in plan with line from 2 in elevation gives the second point, *l*; while the third point, *m*, is obtained by the intersection of the line from point 3 in plan with the line from point 3 in elevation. This gives half of the complete winding or screw line, which is on the side nearest the spectator, and is therefore seen in full line. The other half, on the opposite side of the cylinder, is in dotted line, and the points through which it passes are obtained by an inclination upwards of the same lines as before, starting from points 1, 2 and 3 in plan, intersecting them from points 5, 6 and 7 in elevation. These points in reality are the same as if obtained by drawing verticals from points 5, 6 and 7 in plan; but as the circle or plan is divided into eight equal parts, 5, 6, and 7 are opposite to 3, 2 and 1. If the circle in plan was unequally divided, the points of upper half of helical line going from *n* to *a* would be obtained by the lines from 5, 6 and 7 in elevation, including those which would be drawn from the points in upper side of plan, as those with the plan unequally divided would not be opposite points in the lower half. But the principle is the same in every case: that correspondingly numbered horizontal lines intersecting with correspondingly numbered verticals give the points in lower and upper parts of the helical or screw line.

Fig. 4, Plate CLXXXV., illustrates the point to which we have in a preceding paragraph just referred: namely, the difference between a quick-running screw line, as in last figure, and a slow-running one, as in the present figure. Here the "pitch," *b e*, is only one-half that of fig. 1, Plate CLXXXII.; although we have shown in dotted lines an intersection of the cylinder in order to illustrate more clearly the course of the helical line, both at back and front view of the cylinder. The complete turn of the line is from *b* to *f* and from *f* to *e*; the part at front of the cylinder being in full and hatched line *b* to *f*; the part of line at back of cylinder being on dotted line from *f* to *e*. The corresponding helical line, but running in the contrary direction, is shown also in dotted line, as from *c* to 4, and from 4 to *g*, and from *g* to *h*.

In fig. 3, Plate CLXXXII., we illustrate a conical, helical or screw line. This is shown as being generated by a point going round and up the surface of the frustum of a cone, *a b c d*. As in the curve of the cylinder, the projection in plan of base, as in A, is required, as well as the plan of top, as in C. The two plans, A and C, may be obviously combined in one, as shown by the two circles, *f g h* being the plan of base *a b* in B, *j i k* being the plan of top, *c d*. Half only of the projections of plan are in this case absolutely necessary, as from the circle being divided into eight equal parts, the divisions on upper side coincide with those on lower. If the divisions were such that the points on upper side did not coincide with those on the lower, the plan or circle would require to be complete, as the vertical lines starting from points on upper side would be different in position from those starting from the points in lower side, although all would be parallel to the centre line *k e*. Divide the plan, as *f g h*, into any number of equal parts, and from these, as 1 2 3 in A, carry up vertical lines cutting *a b* in points *l* and *m*. We have, to make the construction more clear, put the plan of top above the elevation in B, as at C; this then is divided into the same number of equal parts as A is divided into, and from the points 1, 2, 3, verticals are dropped to cut *c d* of frustum of cone in points *n* and *o*. These points would obviously also be gained by carrying up verticals from the points in inner circle *j i k* in A, as from 4 and 5; but by placing the plan of top at C we obviate any confusing lines in B. Join the points *l*, *n*, and *m*, *o*. Let *a c* in B be the "pitch" of the helical or screw line. Divide this into the same number—eight in the diagram—as the plans (full) are divided into, and from points 1, 2, 3, etc., in *a c* draw lines parallel to the base *a b*. The intersection of the corresponding

lines gives points, as at *p*, *q* and *r*, through which the curve of helical line is to be drawn.

Delineation of Helical Bodies.

In fig. 4, Plate CLXXXII., we give an illustration showing the application of the foregoing methods of drawing helical or screw curves to the delineation of the "worm" of a distilling apparatus, the "worm" being generally a true helix. The diameter of the pipe forming the worm we assume to be equal to *d b* in A. The worm in this instance is a cylindrical helix, as in fig. 4, Plate CLXXXV., not a conical one, as in fig. 3, Plate CLXXXII.: the diameter is therefore equal throughout of the "coil" of pipe forming the helical worm. The curve of the helix is generated by a moving point in an imaginary cylinder, the circumference of which passes through points lying midway between the sides of the pipe. To describe the curve three points must be known: first, the diameter of the "coil," as *d b* in A, fig. 4, Plate CLXXXII.; second, the diameter of the pipe, as *a b*; and third, the length or height of the "pitch" line, as *f g* in B. The first thing to do is to divide the diameter of the "coil," as *d b*, into two equal parts in the point *e*, and through *e* at right angles to draw a centre line, *e h*, of indefinite length. Next divide the diameter of the "pipe" or tube *a b* into two equal parts in the point *c*, and from *e* as a centre with *e c* as radius describe the circle 12 3 6 9. This circle shown dotted is the circumference of the cylinder, the height of which is equal to *f g*, round which the moving point generates the helical curve. Divide this circle into any number of equal parts, as twelve in the drawing, and divide also the pitch *f g* in B into the same number of equal parts. Then, by drawing verticals from points 1, 2, 3, etc., in A, and horizontals from points 1, 2, 3, etc., in B, points will be given at their intersections, as *j*, *k*, *l*, *m*, *n*, *o*, *p*, *q*, *r*, *s*, *t*, and *u*, through which the curve of the central helical line is to be drawn. Distances equal to *a c*, *a c b*, in A, are then to be set off at various points of this helical curve, and these will give the points through which the "pipe" forming the helical coil will be drawn in full, and shaded if necessary, as shown in the drawing.

Development of a Helice.

We have, with reference to fig. 6, Plate CLXXXII., said something as to the development or stretch-out of a helical screw or curve. That figure, in fact, explains the principle upon which the development on a flat surface of a helical curve is found. Thus, to find the development of the helical curve in fig. 4, Plate CLXXXV., if we take any line of indefinite length, as *a b*, fig. 5, Plate CLXXXII., and make the line *a f* at right angles to it, and its height equal to *a* 8 *c* in fig. 4, Plate CLXXXV., and set off on *a b* a series of distances equal in length and number to the distances into which the circle in A is divided we shall have the data to find a series of points through which the line *f* joining *a b* is to be drawn. Draw through the points *c*, *d*, *e* and *b* verticals, as shown; and on them set off the distances as taken from *b e* in B, fig. 4, Plate CLXXXV. Thus *c g* is equal to *b* 7, *d h* to *b* 6, *e i* to *b* 5, *b j* to *b* 4, and so on; *f*, *g*, *h* and *i* are the points through which the line is to be drawn. To save space, we have assumed the length of line to be as *k m*, fig. 5, Plate CLXXXII., corresponding to the line *a b*—that is, one-half of its true length. The distances (half), as 1 2 3 on the line *k m*, are to be taken from the circle in A, fig. 4, Plate CLXXXV., and the distances, as 1 7, 2 6, 3 5, etc., from the line *b c*. The distance *k l* is equal to (half) of *b e*, fig. 4, same Plate. When the line *l m* is drawn, the triangle *k l m* is the development of the helical line. And if (assuming the distances in the triangle to be the same as those given in fig. 4, Plate CLXXXV.), this be the set in relation to a cylinder the diameter of which is equal to A, and height to *b e* in B, fig. 4, Plate CLXXXV., and the paper wound or wrapped tightly round the cylinder, then the points *l* 7 6 5 4 3 2 1 *m*, fig. 5, Plate CLXXXII., will give the helical curve points on the cylinder.

Development of a Conical Helix.

The development of a conical helix is shown in fig. 1, Plate CLXXXV. To save space we have drawn this figure with distances equal to one-half of those given in fig. 3, Plate CLXXXII., the development of the helical curve of which we wish to obtain. The principle is the same as in last figure, and as the method of developing the surfaces of a curve or of a conical frustum elsewhere described. Let *a b*, fig, 1, Plate CLXXXV., be the centre line of the frustum, of which *a c d e* is one-half in elevation. Continue the side *e d* till it cuts *a b* in *b*. From *b* as a centre, with *b c* as radius, draw an arc of a circle of indefinite length, as *e f*. From *e* set off distances equal in number and in length to those in the circle (or semicircle) A in fig. 3, Plate CLXXII., to point 8 in the arc *c* 8. From these points, as 1, 2, 3, 4, draw lines converging to the point *b*. Take from B, in fig. 3, Plate CLXXXII., the distance *a* 7 (from line *a c*), and set it off from point 1 on arc *e f* (fig. 1, Plate CLXXXV.), to cut the line 1 *b* in point 7. With distances, as *a* 6, *a* 5, etc., from line *a c*, fig. 3, Plate CLXXXII., set off from points 2, 3, etc., on the arc *e f*, to cut the lines 2 *b*, 3 *b*, etc., in the points 6, 5, etc. A series of points will thus be obtained, as 4, 3, 2, and 1, through which a curve line is to be drawn, joining points *d* and 8. The surface *e* 8 *d* is is the development, on a plane, of the helical or screw line in B, fig. 3, Plate CLXXXII. If this were cut out, and the paper applied with its edge, as *e d*, to one side, as *a c*, of the frustum of a curve, as *a b c d*, the edge 8 1 2 3 4 5 6 7 *d* would

form the helical curve. The reader must remember that the distances or dimensions in fig. 1, Plate CLXXXV., are only one-half of those taken from fig. 3, Plate CLXXXII.

Delineation of Helices.

The delineation of screws used in the mechanical arts, both square-threaded and angular-threaded, will be presently shown. The methods usually practised in the delineation of screws on the small scale will also be then illustrated. Meanwhile, this is the appropriate place to show how a helix pipe, or "worm," as in fig. 4, Plate CLXXXII., is delineated on the small scale. This, as will be seen on inspecting fig. 2, Plate CLXXXV., is shown by a combination of straight-lined parts; the only parts which are curved are the ends, as at *a a*. These ends may be finished with semicircles, as at *b*; or, as some prefer to finish them, with semi-ellipses. The parts of the "worm" at *d d* represent the parts seen in the front, or nearest to the spectator, and are made to slope from left to right, as shown. The parts *c c* are the parts at the back, or farthest from the spectator, which lead the "worm" up from the other parts: they thus slope in the opposite direction, from right to left. An angle for the parts *d d* very suitable is about 26°; but, as the "set square of 30° and 60°" can be so easily applied, they might be put in at the angle of 30°, as at *f g h*. But it will be perceived that when finished, as at *i i*, *j j*, the drawing does not look so well; the return parts, as *j j*, in place of appearing to go up, as at *e e*—which they do—are in reality sloping slightly downwards. To give them a sloping appearance upwards, the "worm" would require to have a much quicker running helix. The setting out of the drawings will be understood from an inspection of the centre line *m l*—the distances between the parts *d d* being set off on this, as at *m* and *n*; the lines *o p*, *q r*, bounding their outer lengths, the circular ends being beyond these.

To find the Curves of a Spiral Staircase.

Having in the preceding paragraphs explained the principle upon which screws and helices are projected, we now proceed to show their application to the practical work of the builder and mechanic, as in the setting out of spiral staircases and of screws. And first as to the application of the principle to staircases.

The principle of delineating helical or screw lines is applicable to the setting out of "circular staircases"—sometimes termed "geometrical," and more popularly "corkscrew" staircases. This is illustrated in fig. 3, Plate CLXXXV., in which A represents the plan of the circular "well-hole" formed in the building, which forms what may be called the "case" or "casing" of the stair. Or the circle may also represent the outside diameter of the geometrical staircase, should it be formed of iron, which may stand quite independently of any well-hole or part of the building, as in the centre or the corner of a room, from which access may be desired to a room above. In the drawing the inner circle B represents the well-hole, or it may be of smaller diameter and represent a newel post or vertical post round which the stair winds. Suppose it takes fifteen steps to reach the upper floor at line 15, in C C, from the lower floor or story *c d*. The stair is entered, or the first step starts from the point *e′*, as shown by the arrow *e c′*. The steps in the lower half are shown in full line, and hatched; those in the upper half dotted. If the reader will suppose the staircase to be cut into two parts in the direction of the horizontal line, crossing the plan in A A from point 15, and that he is looking at it full in front in the direction of the arrow 1 at A, he will perceive mentally that the steps will, as they wind round the inner concavity of the well-hole, appear of different lengths, and that their outer terminations will lie in a curved, helical or winding line. Those steps, thus seen as looking at the vertical section in the direction of the arrow, are shown in the projection of elevation in C C; as going from the point *f* on base line *a b c d* up to *i*, opposite the point 8 on the line *g h*. The steps seen in the upper half of our supposed vertical section will be seen to follow a winding line also, when the section is looked at in the direction of the arrow 2; and this winding line is that shown in the projection of elevation in C C reaching from point *i* to *j*.

To obtain the complete winding line from point *f* to *i* and *j*, proceed as follows. Divide the circle in A A into fifteen equal parts—the number of steps in the stairs—and from these points draw lines to the centre of circle at *l*, but stopping at the semicircle as at the point *k*. These lines give the plan or upper face—technically called the "tread"—of the steps. Draw any vertical line *g* 15, equal to and representing the height from the lower floor *c d* to the upper. As this height is reached by fifteen steps, the line *g* 15 is divided into fifteen equal parts, the same as the plan or circle in A A is divided into. From the points 1, 2, 3, etc., on line *g* in C C, horizontal lines are drawn, or parallel to *c d*. And from the points 1, 2, 3, etc., in A A, vertical lines are drawn of an indefinite length. They are drawn in the diagram only of length sufficient to get the point of intersection with the horizontal lines drawn from the points on *g*. The vertical line 15 *f* is drawn, giving the outside point, as *f*, of the staircase. The intersection of vertical from point 1 in A A with the horizontal from point 1 on *g* in C C gives the first point, as *m*. The point *n* is found by the intersection of the vertical from point 2 in A A with the horizontal from point 2 in *g* in C C. All the other points are obtained in the same way; the process being identical with the projections previously described, the last point being at *i*.

THE ORNAMENTAL WOOD WORKER AND DESIGNER,

In Carpentry and Joinery, chiefly for Exterior Work.

(BEING ONE OF THE SUBSECTIONS OF THE PAPER ON "FORM AND COLOUR IN INDUSTRIAL DECORATION.")

CHAPTER V.

AT the end of preceding chapter we described the elements of perforations in woodwork in straight-lined figures, as the triangle and the square, concluding with certain dispositions of the latter. When the sides of the square are not at right angles to each other, as at *i*, fig. 10, last chapter, but as at *l*, the perforation assumes the form of a "rhombus," which is in fact the lozenge square in *k* in another position.

Another four-lined figure is the rectangle or parallelogram, as at *m*. When this is used as a perforation it is generally very narrow—that is, the base, or length, as *p p* in *m*, is very much greater than the height or breadth, *q*, as shown at *n n, o o*. When the rectangle is broad, as at *m*, it is made to assume a more pleasing outline in perforated work when the ends are treated as at *r r* in *s*; this is done by adding two equilateral triangles, as at *r*, *r*; or two scalene triangles, as at *b*. When the angles are not right angles, as in the rectangle or parallelogram at *m*, but as at *l*, in which none of the angles are right angles, the perforation is termed a "rhomboid" in form. We shall see presently how those simple elementary forms may be combined in perforated work; meanwhile glancing at the

Ornamental Arrangements based on the Circle.

Simple forms of the second class of elementary perforations, as in fig. 11. The simplest form is of course the complete circle, as at *a*. When used in this form it pleases the eye best when of small diameter, and still better when used in combination with other perforations more or less elaborate. A combination of two circles or parts of circles is shown at *b* and *c*, *d* and *e*, and of three at *f f g*—which is termed the "trefoil." The "quatrefoil" perforation is at *i j k l*, and "cinquefoil" at *l m n o p*. A combination of two arcs of a circle forms another perforation, as at *q* and *r*; of three at *s*, and of four at *t*.

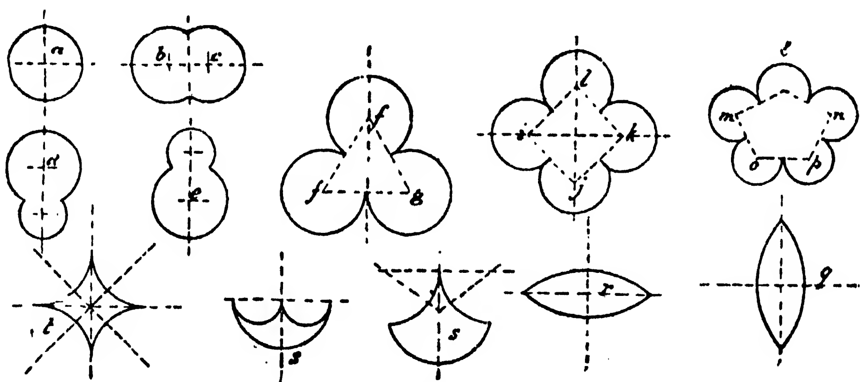


Fig. 11.

Ornamental Forms of Combination of Right-lined Figures.

Although right-lined perforations are rarely used alone in perforated work, still a pleasing effect may be obtained by their combination. We show in the succeeding illustration a few of these combinations, —and this is not done with a direct view that they should be adopted in practice as we give them—although, in combination with other more elaborate perforations in which circular or curved lines are met with, some of these would be very effective. But we give them chiefly to initiate the young designer into the very varied and in some instances complicated designs yet to be illustrated—leading him gradually up from the simplest to the most complex arrangements of straight lines and curved ones.

Thus, in fig. 12 *a a* illustrates a combination of very narrow rectangles: see *n n, o o*, in fig. 10, which we have there named as by no means a pleasing perforation if used wide, as at *m*. This vertical arrangement is sometimes very effective, even when used alone—as forming, for example, a "band," or string course between two more elaborate sets or perforations. A great deal of the effectiveness of this arrangement depends upon the due proportioning of the width of the perforations themselves, but also of the spaces between each two contiguous openings. The vertical direction lends itself obviously with greater ease to a continuous arrangement of perforation of this simple form than the horizontal. The best horizontal continuity is where a single perforation runs along, as at *b c d*. But this has to be separated by full spaces, as at *e* and *f*, otherwise it would assume the form of a mere horizontal slit or slot. In place of having these spaces solid, as *e* and *f*, by filling in this with a perforation lozenge form, as at *g* and *h*, a certain pleasing effect is obtained—and this even where a simple shortening of the perforation is made, as at *i* and *j*. Or perhaps a still more decided variety,

and this as it is more of a contrast, is filling in the blank spaces, as at *e* and *f*, by short perforations of the same form, but placed vertically, as at *k* and *l*. An arrangement of narrow rectangular apertures is shown in which two are vertical, as at *m*, *n*, and two horizontal, as at *o* and *p*. These are placed equidistantly from a central point common to them all. If this central space, in place of being solid, be opened up with a perforation, as at *q*, a certain degree of pleasing variety is introduced. This may be varied in the same line or band in which the arrangement, as

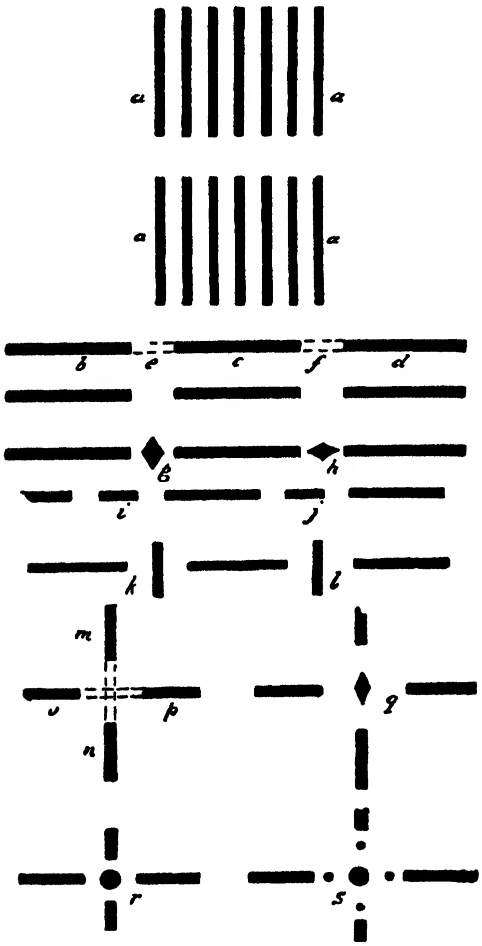


Fig. 12.

m n o p, is repeated, by having the central space opened by a circle, as at *r*; a still higher grade of pleasing variety being obtained by a cluster of small circles round a central larger one, as shown at *s*.

In place of dealing with the rectangular openings, disposed either horizontally, as at *a b c d*, or vertically, as at *a*, or in combination of those two positions, as in *m n o p*, or *q*, *r* and *s*, by giving them angular or oblique positions we introduce a new element of combination. This is illustrated in fig. 13, in which, to the same arrangement as is given at *q*, fig. 12, angular or oblique perforations, as *a*, *b*, *c d*, are added. This is also added to the same arrangement shown at *r*, in fig. 12, and as at *e e*, fig. 13. In this figure the angular or oblique arrangement of the rectangular openings is further

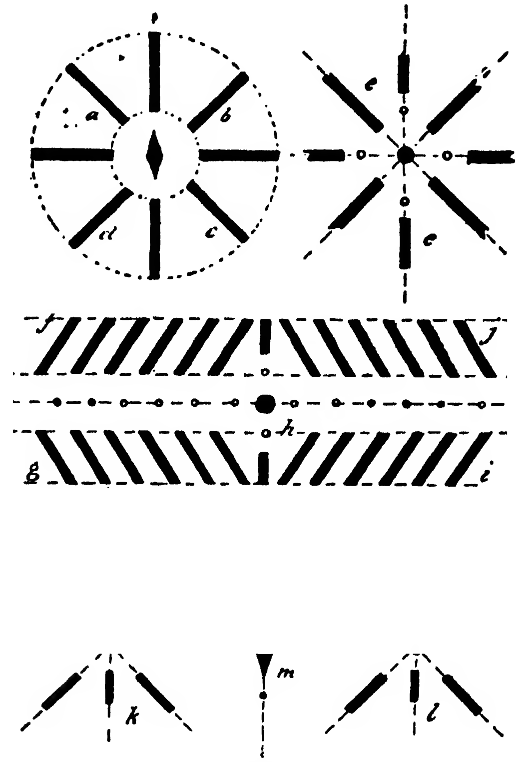


Fig. 18.

illustrated, as at *f*, *g*, the openings sloping, so to say, in reverse directions. The arrangement is repeated on the other side of the central part *h*, as *i*, *j*, the openings, *i*, being in reversed position as compared with

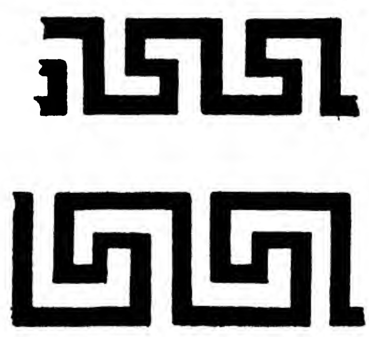


Fig. 14.

f, *j* with *g*. An arrangement of angular perforations is shown at *k* and *l*, these being repeated along the band or line; and each "repeat," as the technical phrase is, being separated by some such arrangement as at *m*. Some of the ornaments called "frets" afford good illustrations of the effect produced by combinations of straight lines: see Plate XLV., figs. 6 and 8.

THE TECHNICAL POINTS CONNECTED WITH THE EMPLOYMENT OF FORM AND COLOUR IN INDUSTRIAL DECORATION.

CHAPTER VII.

Gradation of Form (*continued*).

At conclusion of preceding chapter we pointed out the truth that it is to Nature the student must go for his best lessons. And it is ever to be remembered—what, however, by too many is willingly, at least easily enough forgotten—that what is good in drawing copies and in casts or models is derived from Nature. As from Nature, therefore, all good and true artistic inspirations—as expressed in pictures, drawings, or casts—come, it is obviously only a common-sense, business-like proceeding to go as often as we can to learn, if it may be, some lessons which will supplement the good, if they do not supplant, as it is to be hoped they will, the bad or defective teachings of the class, or of study and private practice.

We have said in last paragraph but one that the effects of gradation are observable more or less decidedly in all natural objects, even in those comparatively few in which the surfaces are flat. We have shown how even in such flat surfaces this gradation is provided for and secured; and the artistic pupil will not regret if such opportunities as may fortunately be within his reach be availed of to study such effects in nature as will be met with in mountainous districts and those localities on our island coasts where grand and imposing sea-shore and cliff effects are to be met with. Let him take the face of the flattest of overhanging or perpendicular cliffs which frowns over green-grassed valley or sand-ribbed sea-beach, and closely study what he sees on it and from it, as he views it at various and varying distances. It will go hard indeed, if only he have the faculty of seeing, if he does not learn some striking lessons from his study: he will at least see the difference between some flat surface of man's work—as, for example, some railway viaduct or bridge—and the flat surface which Nature, with her silent and subtle effects, produces. Our practical men, who pride themselves on being such only and nothing more, are but slow to take such lessons as Nature so lavishly affords us; the probability being, however, that many of those same practical men have not the remotest conception that Nature has lessons which they might with advantage learn; or, if they were told she had, would probably pooh-pooh the notion that their work could in any wise be improved by her. Knowing their work, and how they did it, we may say with some degree of certainty that if the mediæval architect—there were no railway and other engineers in the dark ages, in many things falsely and in gross ignorance so called—had had to deal with the spanning of streets with such material as the modern railway engineer now deals with, they at least would have tried to spare the passers by the nightmare of staring ugliness which our work so liberally gives us. The mediæval constructor would have shown, if not by variety in form at least by effective colour, how such flat surfaces could have been so dignified as to be a delight to look at; in place of, as they do with us, depressing with their bald and staring uniformity of ugly surface.

And if this principle or feature of gradation in shade and colour gives such an infinite variety and an ever delightful and delighting charm to natural objects, no less a charm is imparted, not only by the feature of curvature in form, but the way in which that curvature is gradated or graduated. That curvature is an essential characteristic of natural objects is obvious to all patient observers of them, to all close students of their peculiarities. There is no end to the series of valuable lessons which the art student will gain by a close and honest inquiry into and an examination of the "subtlety and constancy of curvature in all natural forms whatsoever." There are, doubtless, examples enough of straight or right lines in natural objects, but in many these are only "suggestive, not actual," and they are all, as one great master in art points out, necessary, as "without them we could not be sensible of the value of the contrasting curves." While, therefore, the youthful art student must, as part of his preliminary practice, learn to draw curved lines in the widest variety, in some such system as he will find most fully illustrated in the papers under the head of "The Ornamental Draughtsman," he must go to Nature to learn what curvature really is, and to gain from her lessons as to strength, originality and purity of expression in design.

In the interests of our youthful art-student readers, and for the matter of that for those of some students of an older growth, it is scarcely possible to dwell overmuch on the importance of studying nature as a source of that artistic inspiration, or as forming the surest basis or foundation for good work in higher branches, in the importance of beginning at least to closely study the minuter objects of nature. This must at least be said for, in addition to what we have already said of them,—that they are for the most part within easy reach of every art student. Neither the means nor the time is given to every student to study nature in its grandest aspects, by river-bank, sea-shore, or in mountain range. But as the little gifts and graces of humanity are within the bestowal of those who in "the huts of poor men lie," so are the minor marvels of nature within the reach of most. We have seen what lesson may be obtained from the stones of the wayside; they can be gathered as

readily from the grass of the field. Fit only to be trodden under foot, nibbled at by the frisky lamb or cropt by the patient cow,—not much surely in it of lessons for the art student? No! if looked at as most of us look at it, without either bestowing a thought upon the graciousness of its gifts to man, or deeming, indeed, that it is worth at all looking at—giving, in truth, no thought whatever to it, save, perhaps, that it is soft to walk upon, or in good order for a game of lawn tennis, cricket, or croquet. Yes! if looked at with the seeing eye or the eye desirous to see. Not much, perhaps, it may be thought to show in winter-time, when brushed by cold sweeping rains, or covered tenderly with wreaths of hoar frost, but even then as rich in its artistic as in its intellectual and moral lessons. But what of it when the warm winds of spring and its gentle showers have brought upon its blades a fresher green, a lovelier tint and hue? and what of it when buttercups and daisies, wild anemones and shooting hyacinths or bluebells, make it a perfect plain of delight, a veritable field of cloth of gold, of silver, of opal, of emerald, and of amethyst? But if in its wide expanse a thing thus of beauty to the eye, a joy for ever to the pure of mind, the which if an artist could display on canvas as it is would give him a place in art which no artist, the best who ever lived, has yet occupied, it is no less a suggestive field for study when taken in detail—all the better, perhaps, studied thus. A single clump might be said to be the study of a season; and in truth no season, however long, would give ample scope and verge enough to gather all its lessons, which have been well said by a keen observer to be work enough for an artistic life. A single blade will, indeed, give a few lessons of worth to the art student. Not much to look at truly. "Nothing, as it seems, there of notable goodness or beauty: a very little strength, and a very little tallness, and a few delicate long lines ending in a point." Not much to look at, but so much to paint or draw, that if our youthful art student could but paint it as it is, he, though doing thus a little thing, would have high claim to be considered a truly great artist. It may well be doubted, indeed, whether any painter, living or dead, has ever given us a true picture of the lowly and despised grass, "made, as it seems, only to be trodden on to-day, and to-morrow only to be cast into the oven" or thrown upon the dung heap. "And yet think of it well," says one who has as keen an eye, a love as warm for the grass of the field as for the grander developments of natural beauties, "yet think of it well, and judge whether of all gorgeous flowers that beam in summer air, and of all strong and goodly trees, pleasant to the eyes or good for food—stately palm and pine, strong ash and oak, scented citron, burdened vine—there be any by man so deeply loved, by God so highly graced, as that narrow point of feeble green." Need we say that there is but one art critic who has written about and seen so much in grass as this and more. The more the art student learns to love the things of nature, the more clearly he sees in them the evidences of the beneficence of the great Creator, the higher and the wider will be the sources of his art inspirations. The writer of these lines is a profound believer in the truth that the better a man is, the better an artist he will be—always, of course, supposing that he has the true artist feeling and capabilities of doing work. And that work must be all the more valuable, as it would be the more valued, the purer, the nobler his thoughts. Impure minds cannot from the very nature of things give out pure thoughts and do pure work. As the fountain, so the waters which flow from it. And if the great art critic whom we are proud to own as a master in the Israel of art had done nothing else than to point out, in language which is in itself a delight to read—" thoughts that breathe and words that burn"—the true sources of high and noble thought in art, and how best to attain to ability and purity in work, the world of art is under obligations to him which it will be difficult indeed to repay. It is not so easy for even the best, amidst the clash and clang of warring interests, the temptations of selfishness and the urging of vanity, to keep the banner of our honour unsullied; but what it is good for us to be warned, as our great authority warns us against, are those evil influences surrounding us, which, as numerous as they are powerful, are ever urging us to courses in life which, in place of making us better men, are but too apt, to use his own words, so to act upon us that "heavenly hope may grow faint amidst the full fruition of the world; that selfishness may take place of undemanded devotion, compassion be lost in vain-glory, and love in dissimulation; that enervation may succeed to strength, apathy to patience; and the noise of jarring words and the foulness of dark thoughts to the earnest purity of the girded loins and the burning lamp." As we have said, so again we repeat, we are ambitious for our young students to whom is intrusted the art of the future. Art has done much in times past, but it may do yet vastly more in the times to come, in elevating the tone, ministering to the higher intellect, and in nourishing purity of thought and earnestness of purpose in the great mass of the general public, much of which has as yet been untouched by the leaven of a higher life. But art can only do this when it is itself pure, and the exponent of those higher feelings and nobler aspirations without which its followers can never do the highest work which will exert the influence in the future which we have named.

THE IRON MAKER:

THE DETAILS OF HIS WORK AND THE PRINCIPLES OF ITS PROCESSES.

CHAPTER XVII.

The Wrought Iron Manufacture.—The Rolling Process.

A BRIEF explanation of the process of rolling, and of the principle upon which it is based, will be useful to the young reader here. Rollers, or rolls, are of course circular in section, giving the rounded form which enables them to be moved or "rolled" along a flat surface with the least possible friction,—hence the name "rollers." Let him suppose two rollers, part of which are shown in fig. 2, Plate CXC., at *a a*, *b b*, to have perfectly flat and level surfaces, so that when placed one upon the other they will lie perfectly parallel to each other. Suppose further that the rollers are provided with shafts or spindles passing through their centres from end to end, so that they can be supported between upright bearings on standards or framing, and so that the centre of one, as *a*, fig. 3, Plate CXC., is vertically above the centre *b* of the other. These centres may be so far apart that in place of the peripheries or circular surfaces of the rollers touching or being closely in contact with each other, there may be a distance of say an inch between them, as represented by the thick line *c c* in fig. 2, Plate CXC. Thus adjusted, we suppose that a motion of revolution is given to the rollers, so that they revolve or "roll" in the same direction. Let the young reader suppose now that he has some cohesive plastic material, such as putty, and this in the form of a longish flat piece, and of thickness equal say to two inches. By presenting this to the rollers *a* and *b*, fig. 3, Plate CXC., as at *c*, these, as they revolve, will draw in the flat piece of putty, and as the space left between them has been supposed to be equal to one inch, as represented by the thick line *c c* in fig. 2, Plate CXC., the result will be that on the plate of putty passing out at the other side of the rolls, as at *d*, it will be now reduced in thickness from two inches to one inch. And as a necessary consequence it will be increased in breadth and in length. By having a method of increasing or decreasing the distance between the centres *a* and *b*, fig. 3, Plate CXC., of the two rollers, it is obvious that the free space between them, as represented by the thick line *c c* in fig. 2, Plate CXC., will be increased or decreased at pleasure, so that we can have thick or thin plates, as desired. The method of adjusting the centres, and thus increasing the distance between the rolls, may be illustrated by the simple diagram in fig. 3, Plate CXC. In this *a a* represents part of the framing in which the bearings of the shafts of the rollers are supported; *b* is the centre of the lower roller, which is fixed at a certain point in the height of the standard *a a*. The shaft *c* is carried in a movable bearing *d d*, which slides up and down on the sides of the standard *a a*, its vertical rise or fall, which determines the distance between the centre of shaft *c* and the centre *b* of lower shaft, being regulated as desired by the screw *e c*, which is turned round by appropriate means.

So far for the action of two rollers working nearly in contact with and parallel to each other, in the production of plane or flat surfaced objects; we have now to consider how objects of differing sections, as squares, oblongs or parallelograms, circular or other sections, may be obtained. Take a cylindrical roller, part of which is shown at *d d* in fig. 2, Plate CXC., and cut a groove all round its periphery of the form of the rectangle *e*. Do the same with another roller, *f f*, as at *g*; place the two rollers parallel to and in contact with each other, as at *h h*, corresponding to *d d*, and *i i*, corresponding to *f f*; then the two rectangles, *e* and *g*, one in each, will form a square aperture, as at *j*. And if the rollers be made to rotate with sufficient power or "grip," any roughly formed bar somewhat like but larger than the square *j* will be pulled through this space and have a section given to it precisely of the form and size of this.

The Wrought Iron Manufacture.—The Rolling Process (*continued*).

Returning now to the operations gone through in the production of the various forms of commercial wrought iron, the next process in sequence after the hammering or shingling of the puddled "ball" into the form of a rough bar, rectangular in section—some twenty inches long, and four or five thick—is the passing of it through the first series of rollers. These are called "shingling rolls," from the fact that their work follows immediately upon and may be said to form part of the shingling or hammering process. The rollers, or "rolls" as they are more generally termed, vary in the section or shape which they give to the bar, this varying according to the different notions of makers; but the object in all the arrangement of the "shingling rolls" is to reduce the "bloom" or rough bar of iron produced by the shingling or hammering to the form of a flat bar. This is of course of varying length, according to the size of the "bloom," but is in breadth generally some four to five inches, and thickness half an inch or slightly over. The form or section of the rolls through which the bloom is first passed is such as to promote the squeezing or compressing action of the rollers in condensing, so to say, or lessening the size of bloom. This compressing action is required in order to complete the squeezing out of such portions of "cinder" as may and generally do remain in the bloom after it has passed through the shingling or hammering

process. A form of section which is found to aid this squeezing out of the cinder from the bloom is shown at *s*, in fig. 4, Plate CXC. (*ante*). This form is maintained for two or three rolls, each succeeding "hole," so to call it, being, of course, less than the preceding. This section is followed by one rectangular in section, somewhat like *j* in fig. 2, Plate CXC., and the section of each succeeding roll approaches more and more to the oblong form, the length exceeding the breadth, till the flat bar of the desired breadth and thickness is obtained. The method of arranging the different sections in one roll or roller and in one frame or standard, and of passing the bloom through the sections in succession, from the first to the last or final section, will be found illustrated and described in a future paragraph.

The Wrought Iron Manufacture.—The Cutting of the Flat Shingled Bars into Lengths.

Although much of the "cinder," or what would popularly be called scales, of which showers in the form of vivid sparks are forced out by the hammering or shingling process, is got rid of, first by this process, and second by that of the shingling rolls or rolling, still a large amount of impurity is present in the flat bars, the product of the last-named operation. While its malleability is also increased, this, in the form of the shingled flat bars, is still below the degree required for constructive purposes—while the general roughness which the bars present has to be got rid of—till the final product, ready for the market, presents all the external and internal characteristics which the market demands. A series of operations has therefore yet to be gone through. The first of these is the cutting of the shingled bars into short lengths. This, in the old works, where the shingling hammer, as in fig. 1, Plate CXC., was used, was done by a cutting machine, forming part of the shingling hammer mechanism. This cutter is illustrated in fig. 6. In this *a a* represents the drum, which, with its projecting lappets, works the tilt hammer already described in fig. 1. To the face of this a pin, *c*, is fixed, and projecting from it affords a centre for the eye of a link or connecting rod, *d*. The lower end of this is provided with an eye, centred to a pin projecting from the face of a lever, *e e*, working at one end of a frame securely fixed to the general foundation of the tilt hammer in fig. 1, Plate CXC. This lever, *e e*, works within a vertical standard, *g*, forming part of the framing, and carries at its extremity, *h*, and on its lower edge, a sharp cutting steel blade, represented by the dark line. Below it, and secured to the framing, another steel cutting edge, *i*, is fixed. As the centre of the pin or steel, *c*, is eccentric to the true centre, *b*, of the wiper drum, *a a*, the result of this mechanical arrangement is that a reciprocating or up-and-down motion is given to the rod or link, *d*, and a similar motion through it to the lever *e e*, working on the centre, so that an alternate closing and shutting of the two jaws, so to say, *h* and *i*, is produced. A bar, then, which may be introduced between the cutting edges, as the edge *h*, rising in the direction of the arrow *j*, when it descends as at arrow *k* will be cut or divided into two by its being forced up against the lower cutting edge, *i*. Various forms of bar cutters are used. But the best and most recently introduced bar cutter is on the principle of the circular saw, used almost exclusively in our large steel works, for cutting the great lengths of steel rails, made by the new methods of working, into the shorter lengths demanded for railway purposes. This saw is a steel disc, with plain—not serrated—cutting edge or periphery of large diameter, and made to revolve at a great velocity. The bars to be cut are laid in a stand close to the ground, and by a peculiarly ingenious arrangement the steel circular saw is brought up to the bar, and, revolving at a very high velocity, cuts it in a second or two. So quickly is the work performed that the eye has a difficulty to see the cutting done, this being almost literally instantaneous. While the cutting is being done, a stream of cold water passes over the bar. This is also the case when the simpler cutting apparatus is employed to cut the shingled bars.

The Wrought Iron Manufacture.—"Piling" of the Cut Bars —The Re-heating Furnace.

The cut bars, in length about twelve inches, are taken and placed together, so as to form what is technically called a "pile," as in fig. 5, Plate CXC., the number of flat bars varying according to the size of the finished bar required. These "piles" are taken and placed in a furnace, termed the "re-heating," sometimes the "mill furnace." This in arrangement is very similar to the puddling furnace, as will be seen from the diagram of it given in fig. 7, Plate CXC., comparing it with that in fig 6, Plate CLXXXIII. In fig. 7, Plate CXC., *a* shows the position of fire bars in which the fuel is consumed to give the high welding temperature required. The fuel (coal) is supplied by the door at end, as shown; *c c* is the hearth or floor of the furnace in which the "piles" are placed to be brought to a white or welding heat, these being introduced into the interior by the door or opening *d*; the furnace roof is at *e e*, *f* being the flue leading to the stack or chimney.

The Wrought Iron Manufacture.—The Re-heating Furnace Operation.

The proper heating of the piles in the re-heating furnace requires the exercise of considerable skill and great carefulness of adjustment of his work on the part of the workman, who is not called, as one would suppose, a piler, but a "faller." For if the piles are allowed to remain longer in the furnace than is

absolutely necessary to bring the iron to its proper degree of welding heat, it is burnt—that is, actually condensed or oxidised, so that a large actual loss of material is occasioned. And failing the over-heating reaching this stage, any lesser degree brings about a proportionate loss, in a deteriorated or lower value in the quality of the iron. Situated as the process of "piling," with its succeeding work of falling, is between two other processes, that which precedes and that which follows it, the "faller," in order to prevent the losses above stated, must arrange his work so as to meet the supply of his piles, which come from the shingling rods and cutters, so that he will in time be able to meet the demand of the workmen who follow him, engaged in the process of finishing rolling. And while the management of his work as a whole has thus to engage his attention, that of the individual piles no less calls for his careful skill. Each pile, as it is prepared at the cutter, is taken and deposited, by means of a shovel-like tool, on the bench *c c*, fig 7, Plate CXC., the floor or surface of which is finished off with a bed of sand on which the piles lie. This depositing of the piles in the furnace requires to be done with great care, so as not to disturb the arrangement of its plates or bars. For it is obvious that the object of uniform heating of the whole would not be gained, were the plates so disturbed that some would project beyond others. Projecting parts thus formed would, indeed, be not only more rapidly heated, being thinner than the general bulk of the pile, but with the intense heat of the furnace would actually be consumed or burned away; so that a direct loss of material would be the result of careless handling of the mass of each pile. We have said that the piles vary in bulk according to the finished size of the bar or bloom required. And although the furnace is supplied for the time being with piles of a uniform size, so as to work off a lot of uniform bars, it by no means follows that the heating of any one pile will take the same time as another. The nature of the process of furnace heating by coal precludes the possibility of securing the uniform heating of all the piles. As, therefore, one pile will be ready for the next process before another, and as we have seen that a pile when ready should be withdrawn from the furnace, or loss of metal or deterioration of its quality will be the result, the greatest watchfulness of the workman is demanded, so that he will be able to see the condition in which all the piles in his furnace are.

Wrought Iron Manufacture.—Rolling Processes—The Roughing Rolls.

We have now brought the manufacture of wrought iron to the point where the pile of shingled bars is heated in the reheating furnace. On being brought to the proper degree of heat, the piles are taken out and passed through a series of rolling mills, which give the iron the various forms and dimensions of bar iron—square and flat—and of cylindrical rods, technically called bolts. To meet the requirements of the market a great number of different formed and sized rolls have to be kept in stock, demanding a large outlay of capital. The rolls or rolling mills are divided into two classes—the "roughing" and "finishing." They are, in principle of working and construction, precisely the same; the only practical difference being that the "roughing rolls" give sections larger than the sections which have to be sent into the market in the finished condition, the smaller-sized sections being given in what are hence called the "finishing" rolls or rolling mills. We have seen how the sections required are given to the rollers by cutting grooves, as *e g*, fig. 2, Plate CXC., which give, when the rollers are placed near each other, a square section. The square section is in practice, however, obtained by cutting the groove diagonally, each roller, as *q* and *r*, fig. 4, thus giving the position to the bar known as the diagonal square, as at *p*. There is a set or series of such grooves in each "rolling mill"; beginning at one end with the largest and ending with the smallest sized section. This is illustrated in the diagram A in fig. 1, Plate CCXII., which will give a fair idea of the general arrangement and construction of a rolling mill, the diagram representing one for making "bolts" or cylindrical rods. The rollers *a a*, *b b*, are placed between standards or upright frames *c c*, *d d*, of great strength, and firmly braced together and bolted to a strong foundation. *e e*, *f f*, are the shafts, and *g h* the cog or toothed wheels by which motion is communicated to the rollers. This motion is in the same direction in each, as shown by the arrows *a*, *b*, in fig. 2, Plate CCXIII.; that is, both revolve towards the centre line, as *c*, so that the bar of iron presented, as at *c*, is drawn in and passed through between them to the other or opposite side, as *d*. This involves a motion of the two rollers—the upper, for example, as *e*, revolving from the right to the left, represented by arrow *g*; the lower roller, as *f*, revolving in the opposite direction, or from the left to the right, represented by arrow *h*. This motion is always continuous in general mills.

From this the reader will perceive a result in the practical rolling of bars which is a great loss of time. Let us suppose that *i i*, *j j*, fig. 2, Plate CCXII., are two rollers, giving the sections as shown in the dark parts. Let *k k* be the plan of the set, as looking vertically down upon *i i*, *j j*—one only of the rolls, as *i i*, being seen, as at *k k*. We have said that the motion of the rolls is always continuously carried on in the same direction, as at *e f*. Suppose that the bar is passed through the section *l* in plan *l'*, in the direc-

tion of arrow *m*, it comes out on the other side, as at *n*. The quickest way to continue the rolling would obviously be to pass it through the next section or roll, as *o*—in plan *o'*—on the same side as *n*—that is, in the direction of the arrow *p*. But remembering that the motion of revolution of the rollers is continuous, in the same direction as that passed through it from side *m* to side *n*, the rollers *i j*, represented in section at *q* and *r*, cannot possibly have any "grip" upon the plate. The very opposite of this, for they fly away from each other, so to say, as shown by the arrows *s* and *t*, in place of approaching each other, as at *u* and *v*, towards *w*. And it is only by successive points in the peripheries of the rollers approaching each other towards the centre that the grip and consequent binding-in power of the rollers is obtained. In rolling mills, as generally constructed, all the "grip" is on one side of the mill, as on the side *m x*; all the loosening of this on the opposite side, as *n p*.

The way in which, in practice, this difficulty is overcome, is this. On being passed by one set of men through from side *m* (see fig. 2, Plate CCXII.) to side *n*, the bar is taken up by another set at the side *n*, and tossed or passed over to the first set on the side *m*. The bar is then passed through—in direction *x*—the section next in succession, as *o*, to *p*, from which side it is again returned to side *m*, and passed through the next hole at *y*. It thus results practically that as much time is taken up in passing the bars from side *p n* to side *x m* as that taken up in the rolling or passing through the mill from side *x m* to side *p n*.

This method of returning the bars from the loose or relieving side, *s t*, fig. 2, to the gripping side, as *s v*, of the rollers is laborious and costly enough in the case of the ordinary bars of commerce, or what is called common wrought iron. But as construction has improved, and with the manufacture of iron, and especially of steel, has improved in like or nearly as great proportion, it results that bars of larger section and of greater length and weight have to be made; to which the power of hand labour in returning them from one side of the mill to the other is not at all applicable. Various systems of working have been introduced from time to time, by which the bars, etc., have been lifted up and passed over from one side to the other by mechanical means. By far the simplest and most effective system, however, is that used in the steel manufacture, in which rails of such enormous length—often 150 ft. long—are rolled out of a single "ingot" of mild "Bessemer" or "Siemens" steel, where no system of returning by hand labour could possibly be employed. This system is having reversing steam engines as the motive power for working the rolls, and of these the reversing gear is now so admirably made that the motion of the rolls can be changed almost instantaneously. This rail-making—the material being almost always now mild steel—has become one of the most important departments of the trade. The section of the rolls is arranged on the principle shown at *i i*, *j j*, fig. 2, Plate CCXII., two sizes being shown at *m n o*, *j k l* in fig. 4, Plate CXC. To the improvement of the rolling mill great attention has been paid by machinists, and very numerous are the forms and different details of arrangement and construction which have been introduced. Rolling mills are made usually with two rollers in the one frame; these are technically called "two-high" rolls or mills. The other modification is termed a "three-high" mill: in this three rollers are fixed in one frame. Fig. 1, Plate CCXII., is a "two-high."

We give in fig. 3, Plate CCXIII., front elevation, and in fig. 4, same Plate, cross-section, of rolling mills used at the Dowlais iron works, in Wales. In a paper read before the Institution of Mechanical Engineers, the late Mr. William Menelaus, one of our most celebrated modern authorities on the iron manufacture, and manager of the celebrated iron works here named, has the following remarks in connection with these rolling mills—the drawings of which here given are enlarged copies, scale being one twenty-fifth of full size. "It has been long felt that the power of rolling wrought iron of large section and of great lengths has not kept pace with the requirements of engineers, who are hampered in their designs by the impossibility of obtaining iron of sufficient dimensions. For engineering works of any magnitude, bars of great length, considerable width and moderate thickness are frequently required. In the ordinary mode of rolling the length and width of the bar are measured by the power of the engine and the time occupied in rolling. It is obvious that to finish a bar quickly it is necessary that it should be rolled in two directions (see our remarks on this point in a preceding paragraph), to prevent delay; and long and heavy bars can be thus rolled only by an engine of enormous power . . . A simple arrangement of rolls for working in two directions is shown in figs. 3 and 4, Plate CCXII. The lower pair of rolls, P, is driven from the fly-wheel shaft, and under ordinary circumstances will be worked in the usual manner; rolling the bars in one direction and lifting them over the top rail in coming back. When it is necessary to make extra sized bars, the rolls *r r* will be put in the standards and driven from the fly-wheel shaft by a pair of wheels" (*s s*, fig. 2, Plate CCXL.). Since the date of the paper in which these remarks were given, it is but right to state that great improvements have been made in rolling machinery.

THE GEOMETRICAL DRAUGHTSMAN.

HIS WORK IN THE CONSTRUCTION OF THE FIGURES AND PROBLEMS OF PLANE GEOMETRY, USEFUL IN TECHNICAL WORK.

CHAPTER XVIII.

CONTINUING our description of the method of describing the ellipse known as the "gardeners'," we have to point out that the line made by the pin or stake will form the curve of the ellipse as it is moved round first above the line *a b*, then below it, till the point *h* is returned to. By means of this diagram, and the method of drawing it, we can understand the exact definition of the ellipse—namely, that it is a curve made in such a way that the sum of the distances from each point on the curve to two points, as *f* and *g*, within the curve, is always the same. The curve is called the perimeter of the ellipse; the two points *f* and *g* the foci; the longest line within it, as *a b*, the "major axis" or the "transverse diameter"; the shortest line, at right angles to this, as *c d*, the "minor axis" or "conjugate diameter."

Trammel for describing Elliptical Curves.

Elliptical curves on the small scale required by the draughtsman may be obtained by the method last described; but a much more convenient appliance or apparatus is used, known as the "trammel." This is illustrated in elevation in fig. 1, Plate CCXXV., and in plan in fig. 2, same Plate. As shown in the elevation, fig. 1, the long beam has a pencil or drawing point, *a a*, at one of its extremities, and two studs or vertical pieces, *b b*, *c c*, capable of moving along the length of the beam in any desired position by the screws. These pillars or studs are each furnished on their lower part with a pointed pin, intended to enter into and move in grooves formed in a metal cross, as *a b c d*, fig. 2, Plate CCXXV. This cross is at right angles, furnished below with very fine points made to fix it upon the paper, which has to be done in such a way that the grooves are in the direction of the two axes, and their point of intersection, *a e*, above the point of meeting of these same axes. In fig. 2, Plate CCXXV., *f f* is the beam corresponding to beam (fig. 1), *g h* the two pillars (*b c* in fig. 1), and *i* the pencil or penholder corresponding to *a a* in fig. 1. When we wish to draw an ellipse with this instrument, we first fix the point or pin of the pillar *b b*, fig. 1, Plate CCXXV., in such a way that the distance from the point *e* to the point of the pencil *a a*, or to the drawing pen, may be equal to the half of the minor axis. We also fix the point *f* of the second pillar *c c* in such a way that its distance to the point to be drawn may be equal to the half of the major axis. This done, we place the point *h*, fig. 2, Plate CCXXV., in the groove corresponding to the major axis, and the point *g* in that corresponding to the minor one. To draw the curve we pass the point of the pencil or of the drawing pen right over the paper round the cross, taking care that in passing round the points *e* and *f*, fig. 1, do not get out of the groove.

Describing the Curve of an Ellipse by Means of a Straight-edge.

In the last paragraph but one we have described the method employed for describing the curve of an ellipse on a large scale, and usually termed the "gardeners' ellipse," and in the last paragraph the method of describing ellipses by means of the instrument called a "trammel." In fig. 3, Plate CCXXV., we give a method of finding a series of points by means of a piece of stiff cardboard or the edge of a set-square. Let *a b c d* be the two diameters, and 1 2 3 4 part of a strip of stiff cardboard. Mark off on the edge of this a distance from the point *h* to *j*, equal to the half of the transverse diameter or the distance *a e*, the other distance, as *j i*, being equal to half of the conjugate diameter, or equal to *e d*. By always keeping the points *h* and *i* connected with or in contact with the two diameters, and by moving the cardboard from position to position in these diameters, turning round, as it were, from one side, as the side to the left of *c d*, to the other or right, the point *j* will obviously be moved round from left to right; and if the position of *j* be transferred to the paper by a pencil mark or dot, a series of points will be obtained, as at *j*, *r*, *o* and *s*, through which one-half of the curve may be drawn by hand. The more numerous these points are the better. Thus, the point *h* is on the conjugate diameter *c d*, the point *i* is on the transverse diameter *a b*, giving the point *j* as a point in the curve. Another point, as *o*, in the curve is obtained by moving the card 1 2 3 4 till the point *h* is coincident with the point *m* and the point *i* with the point *n*. Another point, as *p*, is obtained by moving the card 1 2 3 4 till the point *h* coincides with the point *u* in the diameter *c d*, and the point *i* with the point *k* in the diameter *a b*. Still another point, as *q*, is obtained by moving the card 1 2 3 4 till the point *h* coincides with the point *u* on *e c*, and the point *i* with *i* on *e a*. Thus, by continually changing the position of the cardboard, as 1 2 3 4, the points *i*, *h*, being always on the two diameters, a series of points will be obtained through which the curve may be drawn by hand.

A Point being given which lies in the Curve of an Ellipse, to find other Points to Complete it.

The two diameters of an ellipse being given, to find the foci. Let *a b*, fig. 3, Plate CCXXV., be the transverse diameter or major axis, and *c d* the conjugate diameter or minor axis. With half of the transverse diameter *a b*, or equal to *a e*, from the point *d* of the conjugate diameter describe an arc

f g, cutting *a b* in *f* and *g*, which are the two foci. All lines proceeding from the foci and joining the curve of the ellipse, as the line *f p* from the focus *f*, are called "vectors."

If a point be given which lies in the curve of an ellipse, and this in direct relation to one of its diameters, as the point *h* in fig. 98, to the transverse diameter or major axis, *a c*, the curve may be finished by finding the other diameter, *q r*, and using these two diameters in any of the methods already described by which to find the number of points through which the complete curve is required to be drawn. To find the distance, as *b q* or *b r*—that is, half the conjugate diameter—let *a c* be the given major axis, or transverse diameter, *h*, *k* or *n* being one point in the curve also given. From the point *h* or *k* or *n* draw lines parallel to the given diameter *a c*, and from same point lines as *h j*, *k l*, *n o*, perpendicular

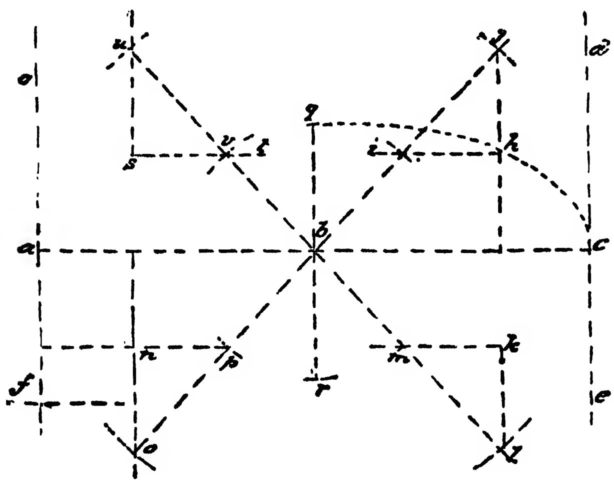


Fig. 98.

to those lines. From the point *b*, bisecting *a c*, as centre, with *b a* as radius, or *b c*, describe an arc cutting *h j* or *k l* or *n o* in the point *j* or *l* or *o*. From the point *j* or *l* or *o* draw a line—or lines—to the point *b*. Where this line cuts the line *i h* in the point *j* will give the distance, as *b i*, equal to half, as *b q*, of the conjugate diameter, which will thus be *q r*. The distances *b p*, *b m*, are also equal to *b q* or *b r*, should *k* or *n* be the given points. The reader will observe that one of the methods of finding the points of an ellipse is based upon this problem.

The method just given is of course applicable to the case in which the minor or conjugate axis is given, along with one point in the curve of its ellipse, but with a slight modification. Thus assume *q r*, fig. 98, to be the conjugate diameter, bisected in point *b*, and *s* to be the given point in the curve. Draw from *s* a line, as *s u*, parallel to the diameter *q r*, and perpendicular to it, *s t*. With half of *q r*, as *b q* or *b r*, as radius, and from *b* as a centre, describe an arc, as *u*, cutting *s t* in point *v*. From point *b* draw through *v* a line which, extended, cuts the line *s u* in the point *u*. The distance *b u* is the half of the transverse diameter or major axis of the ellipse required.

Drawing the Curves of Ellipses through Points found by Intersecting Lines.

We now come to that class of problems or constructions connected with the ellipse in which points in its curves are found by means of lines intersecting one another, as illustrated in fig. 5, Plate CCXVIII. In this the major axis or transverse diameter is *a b*, the conjugate diameter or minor axis *c d*. At the points *a*, *b*, *c*, *d*, lines are drawn parallel to *a b*, *c d*, forming a rectangle, *e f g h*, of which there are four subdivisions, each of which is also a rectangle, as *a i c e*. Each of these subdivisions contains one-fourth of the complete curve forming the ellipse. The principle of this method is shown in the figure. The accuracy of the curve depends upon the care taken in dividing the sides and in drawing the lines through the points of division. In this method the four quarters of the rectangle each contain one-fourth of the curve. This passes through points obtained by the intersection of lines. Those lines are thus obtained. The parts of the sides of the rectangle, or the fourth part of this, as the lengths *c e*, *a c*, are each divided into the *same* number of equal parts—say seven, as in the diagram. From the points of division in each lines are drawn to the point of rectangle opposite, as those on the line *c e* converge to the point *a*; while the lines drawn from the points on the line *a e* converge to the opposite point *c*. The intersection of these lines gives a series of points, and it is through these points that the curve of the ellipse passes. The junction of these points, or in other words the line which passes through these points, is drawn by hand; or the "set curve" may be used. The more numerous the points of division in the lines, as *a e*, *e c*, the more numerous are the points through which the curve passes. And the more numerous those points, the more accurate will the curve be and the easier will it be drawn by hand. For if very near each other, the line or curve joining this will be in effect short straight lines—easily drawn; whereas, if the points through which the curve is to be drawn are widely separated—and this will be the case if the lines, as *c e*, *e a*, are divided into few parts—the line joining any two points will be long, and as this line must be curved, it will consequently be more difficult for the draughtsman to draw the curve accurately than it would be to draw a short and a straight or nearly a straight line. Another point the draughtsman must be careful in—namely, the numbering of the divisions on the lines, as *a e*, *e c*. Unless they be numbered the draughtsman will be apt, at first use of this method,

to get confused as to the lines intersecting which give the points; but if numbered this will be avoided. Care must be taken to number them in correct relation to each other, for it is the intersection of "No. 1" line on *a e* with "No. 1" line on *e c* which gives the first point, No. 2 with No. 2 which gives the second point, and so on. To secure the easy "reading off" of the points, the number must be placed as in the drawing—that is, the point 1 on line *a e* is nearest the point 6 on line *e c*, and so on.

In fig. 6, Plate CCXVIII., we give another illustration of the method of drawing the elliptic curve by this method of intersecting lines. Draw the two axes intersecting each other perpendicularly through the middle, as *a b*, *c d*, in point 3. Divide them each into five equal parts, and set off on each side of an axis, on its prolongation, one of the five parts. Thus, with one of the parts into which *a b* has been divided, set off on the prolonged diameters or axes, from the extremities of these, as from points *a b*, *c d*, to the points *f*, *g*, *h*, *i*. Join these, and we obtain the rhombus or diagonal square or lozenge—*f g h i*. Proceed then as in the foregoing illustration, fig. 5, same plate, by dividing each of the sides of this lozenge into an even number of equal parts, greater in number in proportion as we wish.

In fig. 1, Plate CCXXXIII., we give another method of finding the points of an ellipse by intersecting lines. Let *a b*, *c d*, be the two diameters, intersecting in the point *e*. Through *a b c d* draw lines at right angles to each other, and intersecting at the points *f*, *g*, *h*, *i*, and forming a rectangle. Divide the sides, *a f*, *b i*, and the semi-transverse diameters, *a e*, *e b*, each into the same number of corresponding parts, and number them with relation to each other, as shown. Then through the points on the semi-transverse diameter, as *e*, *b*, draw from the points *c* and *d* lines of indefinite length, as shown, and from the same points, *c* and *d*, lines through the points in the lines *b i*, *b h*. Care must be taken to number the points exactly as shown —the first point (1) on *b e*, being next the first point (1) on the line *b i*—so that the intersecting lines will be correspondent. The points of intersection will give a series of points, as *j*, *k*, *l*, *m*, *n*, through which the curve may be drawn by hand.

Fig. 2, Plate CCXXXIII., shows another method of finding the curve of a semi-ellipse by means of points. Let *a b* be half of the conjugate diameter, *c a* half of the transverse. Produce *b a* indefinitely towards *c'*, and make *a c'* equal to *a b*. Divide *a c* into any number of equal parts, as five, and through these draw lines from the point *c'*. Divide now the side *c d*—found by drawing *c d*, *b d*, parallel to *b a*, *a c*, cutting in the point *d*—into the same number of equal parts as *a c* is divided into. Through these points, from point *b*, draw lines. The intersection of the correspondingly numbered lines will give points as shown. Thus, point *c* is got by the line from point 4 in *a c* cutting the line through point 4 on *c d*, and so on. The other part of the semi-ellipse can be found in the same way; but the points *e*, *f*, *g*, *h*, can be transferred to the other side of *a b* by drawing the ordinates parallel to *a c*—and then setting off the distances, as *b h* to *i*, *g* to *k*, and so on. Fig. 4, Plate CCXXV., is the same method, illustrating a semi-ellipse upon a canted or oblique line, as *b a*. Fig. 3, Plate CCXXXIII., is a canted segment, the height of which is *b c*. The point of the full semi-ellipse transverse diameter is at *c*, so that to find the point *c*, *b c* is to be made equal to *b e*. The young draughstman will observe the peculiarity of the curve of canted elliptical figures, the character of the curve being different at the right-hand side from that at the left.

Difference between the Figure known as the "Ellipse" and that known as the "Oval"—Methods of describing the Oval.

There is an essential difference between these two terms. The oval is a term derived from the Latin word *ovum*, an egg, which in some instances presents a form closely resembling the true ellipse, the ends of which are precisely similar. The egg, however, is perhaps much more frequently met with as presenting one end of smaller size or dimensions than the other; and from this peculiarity the French geometrical draughtsmen have derived a figure to which they have given the name of the "ove," or more generally the "ovale." From this word it is easy to understand how our term "oval" has been obtained. An "oval," then, is a curve which, as its name indicates, has the form of an egg. It is an ellipsis, one end of which is wider than the other. We may consider this figure as the half of an ellipsis according to its small axis, joined to a semicircle, which would have as diameter this small axis. We may thus describe the half-ellipsis by three arcs of circle, two of which are equal. For this let *a b*, fig. 4, Plate CCXXXIII., be the minor axis of the oval, and *d e* the major axis. There are various ways of describing the outline of the ovale or "egg-shaped" figure, some of which we now illustrate. In fig. 4, Plate CCXXXIII., let *a b* be the diameter of the upper part of the egg; bisect this in the point *c*, and at right angles to *a b*, through *c*, draw the line *d e*; from the points *a* and *b* as centres, with the distance *a b* as radius, describe arcs cutting in the point *e*. According as the lower part of the egg is desired to be more or less pointed or sharp, assume any point, as *f*, near to or farther from the point *c*. This will be the centre of the arc, giving curves *a c*, *b c*.

THE MACHINE MAKER OR GENERAL MACHINIST.

SPECIAL EXAMPLES OF HIS WORK—ITS LEADING TECHNICAL PRINCIPLES AND DETAILS.

CHAPTER X.

WHILE the truth of the position referred to at the conclusion of last chapter is admitted on all sides, it is no less a truth, although of course in an obviously limited sense, as regards what are considered to be and are practically established branches of work. And yet we must not fail, as a matter of duty, to point out to the youthful technical reader that there are some who maintain what may be called the "finality doctrine," that in certain branches of work perfection has been attained, or at least that degree of it which the branches are capable of receiving, or the ability to design and the skill to construct of man are capable of giving. Fortunately for the future of the profession, those who maintain this view are not many; but it is all the more from a practical point of view to be regretted that of those few some at least are in positions where, if their personal influence be not directly great, they still possess but too potent powers of popular and extended diffuion of their opinions. And it will be of some practical value to our youthful readers if we give but one example of this finality doctrine of perfection in mechanical engineering work. It has appeared to certain authorities connected with a public body that in the branch of mechanical engineering connected with the steam engine at least a certain degree of perfection has been attained—the point of perfection dating from the period some few years ago. Now, whether since that period there has been any improvement in steam engine work and working, we leave such of our readers as may have been practically connected with the profession to say. Assuredly since then something, we might say a good deal in the way of work, at least has been done, although that work, such as it is, may not coincide with the lines of those authorities above referred to, by which "perfection" is in this view limited, so that, according to them, what has been done has constituted no improvement. But we go much further than this, for the point involved is, we feel assured, one of the most vital importance to the profession. We therefore appeal with some degree of confidence to mechanical engineers, who know the subject of steam-engine work, to say if it be not true that, so far from the stage of finality or "perfection" having been reached in the steam engine, if it be not, as compared with other forms of prime movers, the most wasteful, it certainly is not the most economical. In making this statement we do not appeal to the few who hold isolated and extreme views, but to the wider body of those engineers, who from the extent of their experience and the accuracy of their views really have a claim to be classed as authorities on this great subject. We might, if space permitted, give detailed points showing how very defective a prime motor even the modern steam engine is, in respect of giving a high ratio of effective work for the amount of fuel it consumes. We content ourselves here with the simple statement of the fact, as now given; and with this further illustration of the point under consideration—which to some of our youthful readers may appear as striking enough—namely, that the steam engine even now is very much the same as when it left the hands of James Watt, its great inventor. In principle it is precisely the same, in details of arrangement and construction almost identical; for so thoroughly had Watt grasped the subject, and by a singular prevision of mechanical intellect (if the somewhat paradoxical expression can be allowed) seemed to have so anticipated coming events, that he left comparatively little for his successors to do. What, indeed, they have done has been done to a large extent—almost exclusively, as it might with some truth be said, in the direction of giving more perfect workmanship—that is, displaying a much higher range of mechanical skill in constructive details than in designing certain new but limited modes of working; more this than in initiating any new principles of action.

The machine maker, no less than the technical student, may rest assured, therefore, that the field in which he has to exercise his powers of observation is still wide enough, despite the opinions of those who hold that in some departments finality of effect has been reached—a statement which is the best possible proof that those who hold it have not exercised their powers of observation to any great practical purpose. For knowledge, to a very large extent at least, if it be not wholly, is simply the fruit of storing up the results of things observed. And this knowledge is valuable just in proportion to the accuracy with which observation has been made; so that things noted have been noted as they are, not merely as they appear to be. For this must be here rigidly taken into account by the technical student,—that what one may call knowledge may be worthless for all practically useful purposes, simply because it is not accurate. For one can learn or become acquainted with or observe what is not good as easily, in point of fact sometimes much more easily, than what *is* good. It is a mistake pregnant with practical evils which many young minds hold, that knowledge, simply because this name is given to it, must be good, without any reference as to what this so-called knowledge really is. Observation, then, clearly

demands, if it is to be worth anything at all to the student, that it shall be composed of two things: first, that the observation be guided in a right direction — that is, to subjects and things clearly bearing on his work: it is therefore absurd to direct one's attention, to use a familiar illustration, to apples, when it is wheat one wishes to know about. The second point demanded is that the subject be observed correctly or accurately.

Value of Habits of Observation.

This accurate seeing of things—that is, as they actually are, not as the mind conceives them to be—is absolutely essential to decided success in mechanical design and work. The importance of the considerations noted in preceding paragraph cannot possibly be overestimated; they lie at the root of all success in mechanical work. And this faculty of accurate observation, like the memory, is capable of cultivation; and this cannot be too early begun, nor too closely and honestly carried on. The modes in which this faculty can be promoted and displayed might be numerously cited here, for they are almost as endless as are its objects. But numerous illustrations are not necessary. Two young mechanics—and the illustration may well apply to many of older growth—are supposed to be examining a machine as that from which something useful may be learned, or for some more directly applied information of utility in their daily work. The examination is concluded, and at an after examination of what they have "seen," or what they have "looked" at, it is found that—say with respect to a particular movement or motion—the sketches and the description alike of one are quite different from those of the other. It is obvious that both cannot be the true exposition and explanation of what actually existed, or was carried out, in the machine itself. It is quite possible, of course, that both may be wrong; but if one does turn out to be right, it may, with the most absolute accuracy of statement, be said that it is the exposition of the one who not only looked at the movement or motion, but who actually saw it, or, as we should say, truly observed it—that is, had an intelligent comprehension of what actually did exist in the machine itself. The other, whose exposition was wrong, might not lack the power very intelligently to explain what he thought he saw—might, in fact, have sketched out a movement or motion which might work well enough, only that it would not be that motion which he thought he saw, and persisted in stating that he saw, till, on being brought face to face with it, he was convinced he had not seen. In the one case there had been accurate observation, in the other a lack of it. We can even suppose that while one had a certain part in his sketch-book or in his mind, the other persistently maintained that the machine itself had no such part, the truth being that he must have looked at it in the popular sense of the term "seen it," the not doing *that* being simply an impossibility if he had looked at it at all. But he had not in the true sense of the term seen it, for of it his mind had taken no account. He had only seen, in fact, what his eye had brought with it the power to see, and that power was the exercise of his mind or mental faculties, brought to bear upon the physical act of looking by the eye. This faculty of truly seeing is possessed by some, so to say, naturally in a very remarkable degree. Of such so gifted we say, in reference to his understanding or comprehending thoroughly the characteristics of an object, "he took it in at a glance."

Now this popular expression, unlike many other expressions or phrases which are often vague, indeterminate, and paradoxical, conveys an absolutely sound and valuable truth. The character of the object or nature is really "taken in" by the mind of an acute and quick observer. He does not merely look at physically, but makes his own mentally, what belongs to the object; he thus takes in and absorbs mentally all he requires to know about it. Those who are gifted in this way, other things being equal, make mechanics of the first order, for they can, and do, adapt the same faculty to their own mentally conceived designs. In designing they seem to see at a glance—to use the only expression open to us—all the peculiarities of the design, and how its requirements can be met, so that what to others opens up but what appears to be interminable difficulties, is to them a comparatively easy task.

But this faculty of correctly looking at or taking in the characteristics of objects at a glance, at least quickly or surely, if not as it were naturally given to one, can assuredly be cultivated, as much so as the memory. We are quite aware that some hold that if one has not a good memory naturally, it cannot be acquired. There are many who can give this but too popular notion a clear and decided contradiction by the simple facts of their own experience. To any one of our readers who at present is not in the possession of what is called a good memory, we can, from what we know on the subject, give him with all confidence this comforting advice: Try honestly and anxiously to cultivate—that is, improve—your memory, and this not by fits and starts, but continually, patiently, and, above all, persistently and for a length of time, and you will be certain to succeed. And as with memory so with the faculty of accurate observation. Do not aim at getting all at once—or thinking you have got it—the faculty we have alluded to of "taking it all in at a glance." Be content with, or rather aim at, getting the faculty cultivated by slow degrees; you will be thus all the surer to get it.

THE CABINET MAKER.

The Technical Details, and the Principles affecting the Design of his Work.

CHAPTER V.

Referring to defective work and design at the end of last chapter, we showed how these arose from lack of thought. The same carelessness runs through nearly every department of furniture fittings, fixed or movable. How many fingers have been cut or hands chafed by that highly ingenious contrivance known as a window-blind rack!—although designer and workman would, if they thought at all about it, see that the hand must frequently, with every care, come down in contact with the rack in pulling up or letting down the blind. Yet the corners and edges are sometimes, if not always, made so sharp that they seem purposely designed to give the wounds they but too frequently cause. This point will be pooh-poohed by many. Yet they should remember that life's comfort is made up chiefly of a variety of little things. Each may be very trifling, considered singly, or as only operating for a brief, a very brief period; but as the periods in daily life are so often repeated, if it be disagreeable or painful, the aggregate of the repetitions makes the matter more than a passing nuisance or grievance.

Work to be Done should be done in the Best Possible Way—a Principle not easily Controverted, much Overlooked, however, in Practical Work.

But the principle, nevertheless, is overlooked or neglected in such cases—namely, that whenever work is to be done it should be done in the best and most complete way possible. If a thing is worth doing at all it is worth doing well. And well done work is that which is alone satisfactory. And so far from involving the greatest trouble, from a pretty long and a wide experience of work and of workmen, we firmly believe that of the two it is by far the easier to do good work than to do it in a half-hearted, perfunctory, wholly careless way. We know of nothing so demoralising—we use the term purposely, and in its widest and highest acceptation—as the influence of the notion that there are trifles in all work which may be safely, as they are but too frequently and easily overlooked. There is no such thing as a "trifle" in this sense, in any, no matter what be the kind of work done. If there be, then the whole is a trifle; for every work is made up of a number of details, and if any one detail be a trifle the whole are trifles. To those who believe in trifles the old saying should surely convey an important lesson—"For lack of a nail the shoe was lost, for lack of a shoe the horse was lost, for lack of a horse the rider was lost." Truly a trifle was the nail when weighed against or compared with the value of the life of the horseman; yet the value of the nail was neither more nor less than the measure of the value of the rider,—without the nail the man was lost. It will be a great day for the future of our industries when the opinion is held universally by all engaged in their daily practice that there is not the slightest detail in work which is a trifle and which can with safety be neglected.

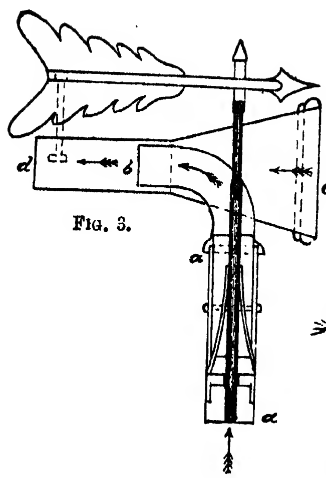
The Habit of Thinking Over and Out of Work to be designed and done by the Cabinet Maker essential to his Success.—Practical Examples.

The habit of thinking out a piece of work, so as thoroughly to comprehend what it is done for, and what are the widest and highest uses which it can serve, cannot be too frequently and too forcibly inculcated. Nor can its importance essential to the welfare of the workman be overestimated. If thought were given to every piece of work we should not see so much of it ministering but very slightly to the end that it professes to serve—in some instances ministering to an end the very opposite, indeed, to that which was its legitimate use. We purpose at this point to show somewhat fully the value of the habit of thinking out and over the purposes which articles of furniture are designed to fulfil, taking as the basis of our remarks two classes of chairs. We would here note that we do not deem it necessary for the purposes of our paper to enter into a like criticism of other parts of furniture. Our object here—which, of course, is involved in the discussion, while giving hints as to the designing of chairs—is specially to lead the youthful cabinet maker to an appreciation of the value of the habit of thinking out all his work, analysing it, so to say; and further, by what we give, to show him the best way to direct his thoughts. Our purpose will be amply fulfilled if we can persuade any one reader to think for himself, not to be guided and influenced by what others do, regardless of whether it be well or ill done. In such matters one is responsible for his own work—no one else can anwer for its doing. Take, for example, a *chair*. What is the essential element of this article of furniture—the reason for its existence? Obviously it is that which ministers to rest or repose; it may minister merely to convenience, as in sitting at a table while taking refreshment, yet even then it is impossible to separate the idea of rest, at least repose, from it. But, as we say, the primary or essential reason for its existence is repose to burdened brain, rest for wearied and exhausted body. Do all chairs give this feeling of rest and repose? Let hundreds answer who have known, who know daily now, how far they are from obtaining either one or the other truly by sitting in a chair. To a certain extent all chairs may be said to give rest and repose, but to be useful both must be complete. As chairs are almost universally made, we have no hesitation in saying that they cannot give completely or fully that species of rest which when even well designed they are calculated only to give. For a chair, rest or

repose is, we do not forget, different in character from that of a sofa, in which a reclining, or a bed, in which a prone or prostrate condition of the body, is the characteristic. But so far as it goes, the rest or repose of a chair is most desirable and necessary for wearied body. We have said that all chairs give, however faultily designed, some degree of rest and repose. But this is not so; for there are some so constructed that they positively give no rest, compel the sitter to be in anything but a condition of repose. Of this type and of all its harm the reader may remember a graphic illustration in Dickens's novel of "The Old Curiosity Shop." The scene is *the* shop—the actors Quilp the dwarf, Brass the oily solicitor, and Quilp's boy, a lad of a kindred genus. Quilp, over thinking how to make those with whom he came in contact as wretched and miserable as he could, was eminently desirous on this occasion to minister to the comfort —in his idea of it—of Brass the solicitor, for whom he had a personal contempt, although he used him for his nefarious purposes. The "happy thought" struck him of making Brass be seated on an old-fashioned, high, straight-backed chair, the seat of which was anything but straight, sloping very considerably forward. The horrors of the situation—the rest which was no true rest, the seat which gave no real sitting—aggravated tenfold by those of tobacco sickness, Brass being urged with fiendish glee by the dwarf to keep on smoking, although merely incidentally, are most graphically, described by the novelist.

Some Notes on the "Philosophy" of Furniture Designing.

What does this incident teach the pupil in cabinet making as to what may be called the philosophy of the design of a chair? It seems a simple thing to make; only something upon which one can sit down. But as it is not mere sitting, but the something which follows, or should follow, this act—that is the point to be considered. This something is, as we have seen, rest and repose. So that to design a chair which will truly give rest is not quite the simple thing it seems at first sight to be. If the pupil will set himself to think over the points involved, he will quickly discover that there are several considerations to be taken into account before the problem can be satisfactorily solved. In the first place he will see that there can be no true rest, no repose to wearied limbs, if any strain is thrown upon them. The muscles must be allowed to relax, if the limbs are to get rested. If, for example, merely to keep himself on the seat, he has to plant his feet on the floor so as to get a point of resistance from which to exert pressure through the medium of his legs, there is a strain thrown upon them which is directly antagonistic to rest and repose. This will be the result if, like the penitential chair of Brass the solicitor, the seat slopes forward. If it slopes considerably, the muscles are being constantly exerted to prevent him sliding forward and off it. If the slope be but trifling, the sitter may not be conscious of making any exertion to keep himself from sliding off it; but he makes the exertion nevertheless, and making it, feels in proportion that his limbs have not been rested. In such a case, likely as not, he rises with the exclamation that he would not have felt half so fatigued had he been standing or walking. There has been a strain on the limbs which in one sense was unnatural, at least unusual; and he feels the fatigue to be all the more on account of it. Although in a much less degree, the same result happens if the seat be perfectly level. Moreover, it is to be noted that by the way in which the chair is upholstered all the effect of a seat sloping forward may be given. Men never do anything without a reason; they may not be conscious of reasoning at all, still they do it intuitively, and a reason they have. When men sitting in a chair fling themselves back and tilt the chair backwards, what is the reason why they do this? Ladies say it is done "because men are so awkward," or "because they are so vulgar." If men who did this were asked to analyse the reason why they were so "awkward," they would soon see the true position of the matter, that they could with safety declare that the awkwardness lay in the chair, not in their action of tilting it back. If they were to get rest and repose at all for their limbs, they felt intuitively that they must obviate the awkwardness of make of the chair by the awkwardness so called of the backward tilt. They felt a strain more or less severe on their limbs when sitting on the chair in its normal position as designed by its maker. They felt this strain to be relieved by putting it in a position never designed by him that it should occupy. Let the pupil cut say half an inch—or better, three-quarters —from off each hind-leg of a chair, keeping the remainder in the way that he has bought them; let him, some evening when he is thoroughly jaded, and finds his legs so that, as the saying is, "he does not know what to do with them," seat himself in one of the ordinary chairs; and then, after some time of sitting, let him betake himself to his "doctored" or amputated chair. Then let him honestly say in which of the two he felt that he derived the greatest comfort of rest and repose. Those who have designed the seats of our second and third class railway carriages of recent introduction have had an idea of such facts as we have named; for they all slope considerably backwards, to the great additional comfort of the passengers, nine-tenths of whom, we undertake to say, could not explain the reason why they were so comfortable; or, if they guessed that it was owing to the sloping seat, higher in front than in back, would not be able to explain why it so acted.



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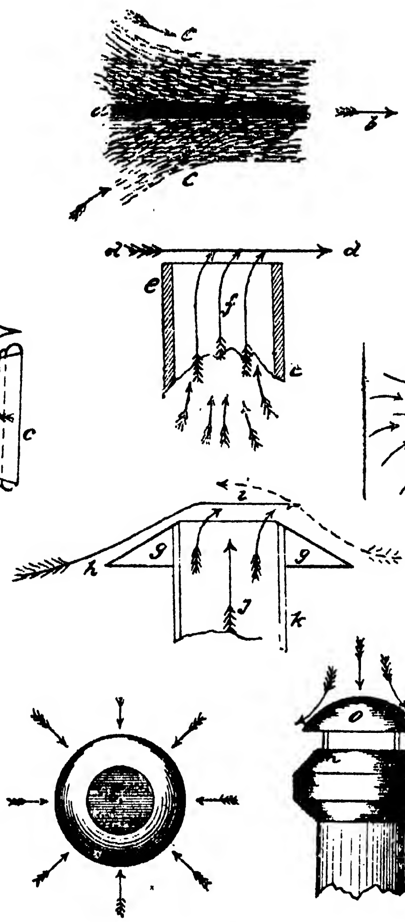

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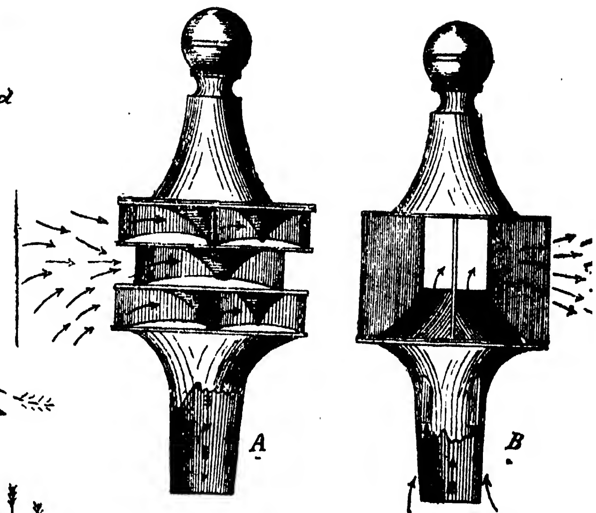

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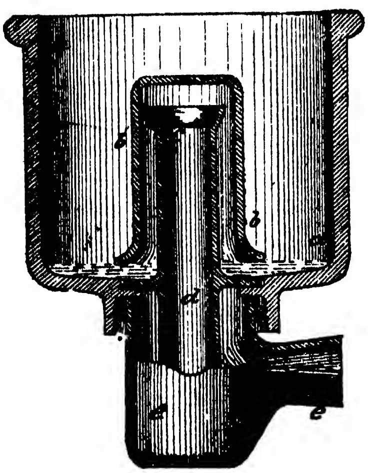

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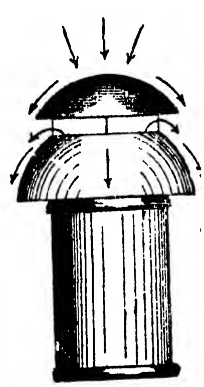

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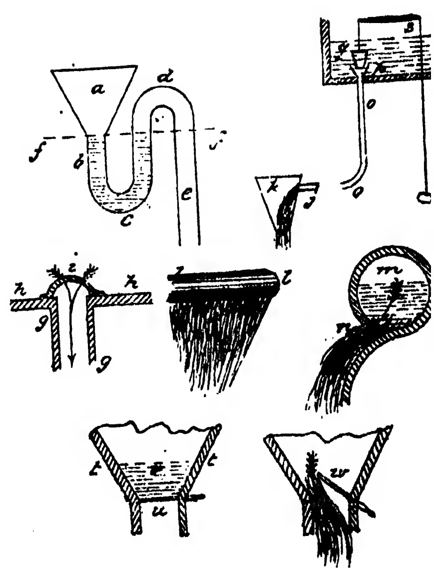
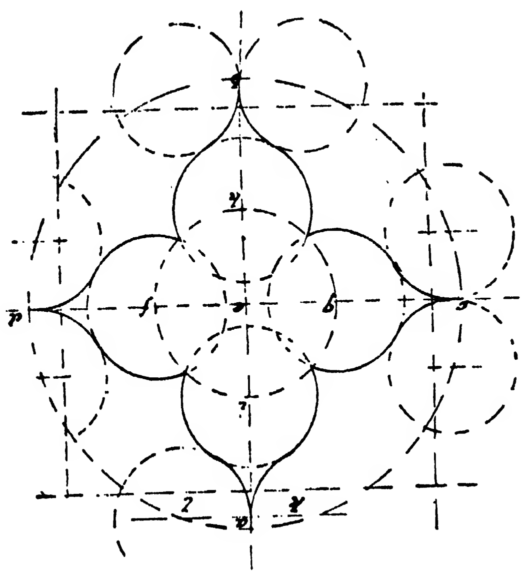


FIG. 6.

THE ORNAMENTAL WORKER IN WOOD.

THE ELEMENTS OF CUT-WOOD WORK.



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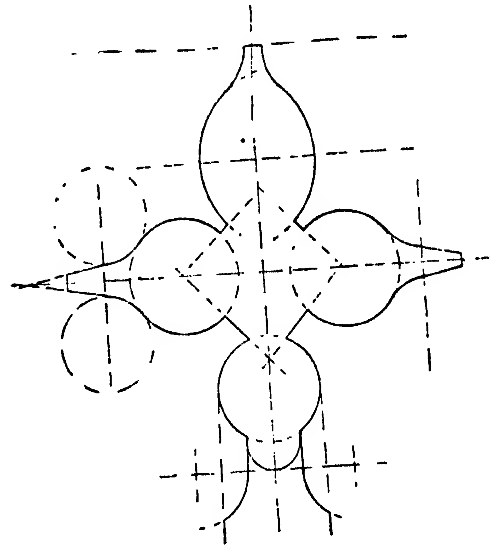

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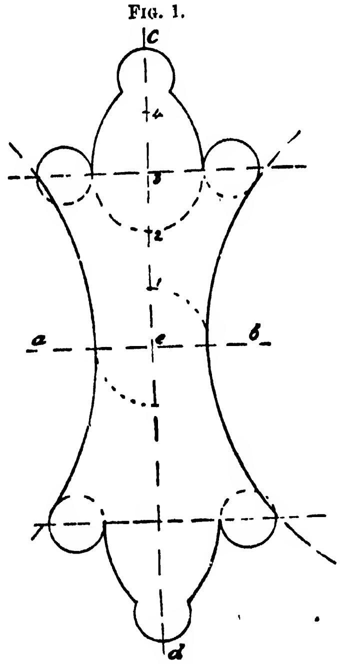

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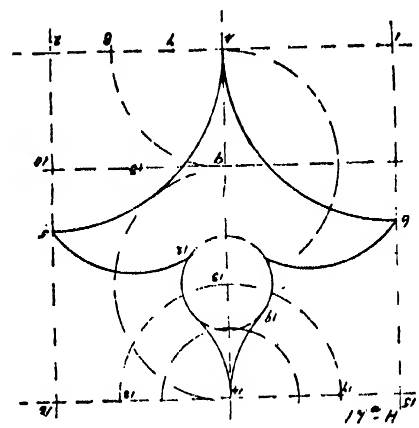

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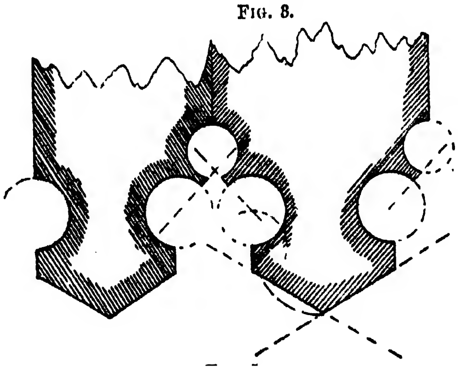

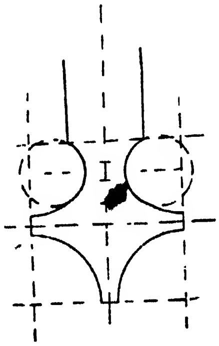

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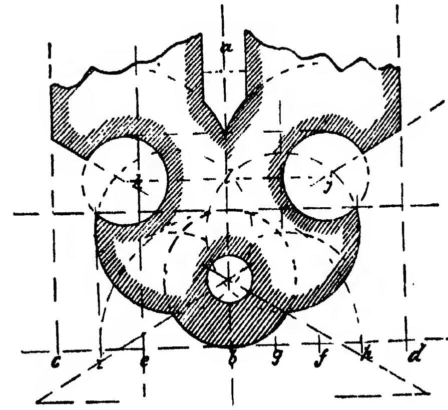
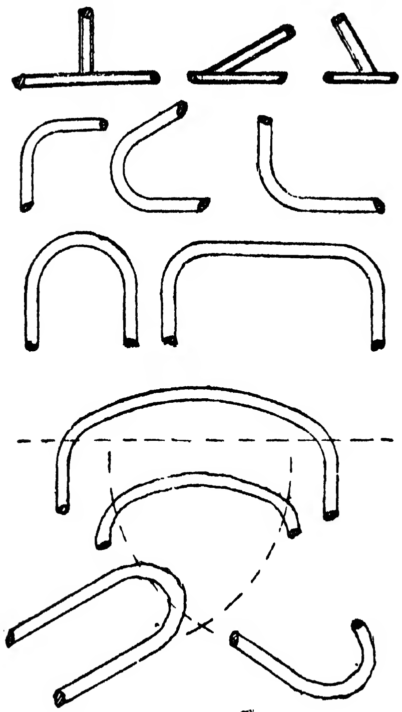


FIG. 7.

THE ORNAMENTAL WORKER IN METAL.

ELEMENTS OF ORNAMENTAL IRON WORK.



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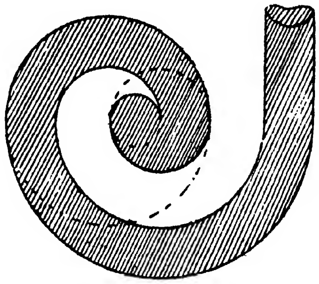

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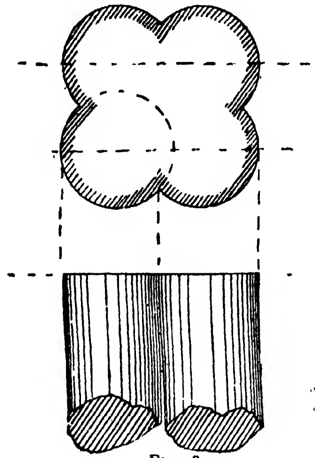

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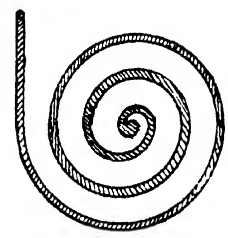

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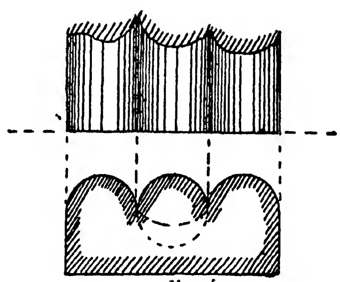

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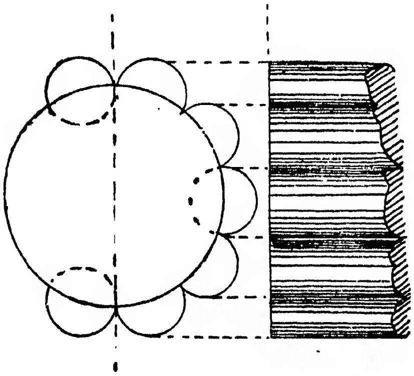

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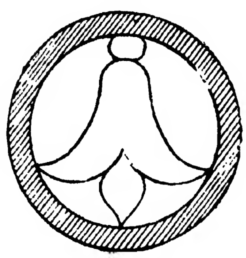


FIG. 7

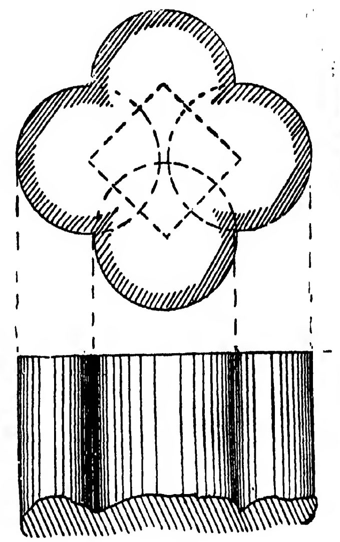


FIG. 8.

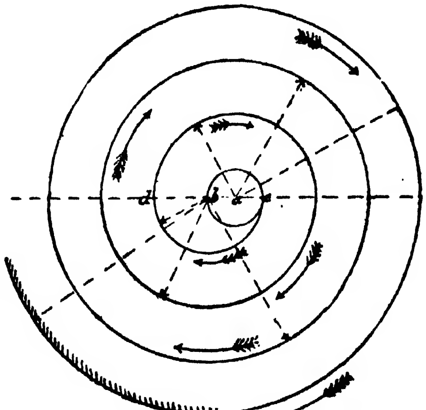
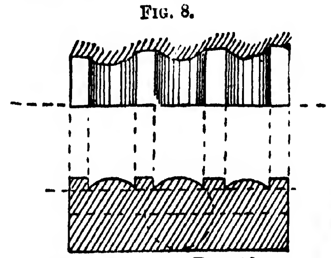


FIG. 9.



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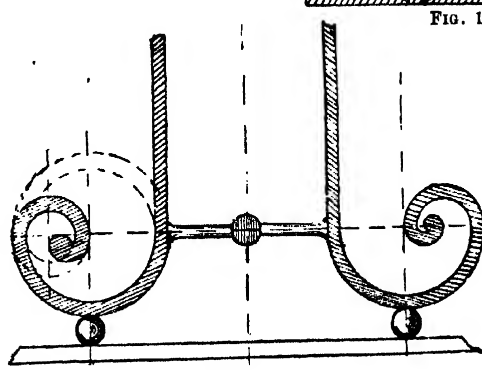
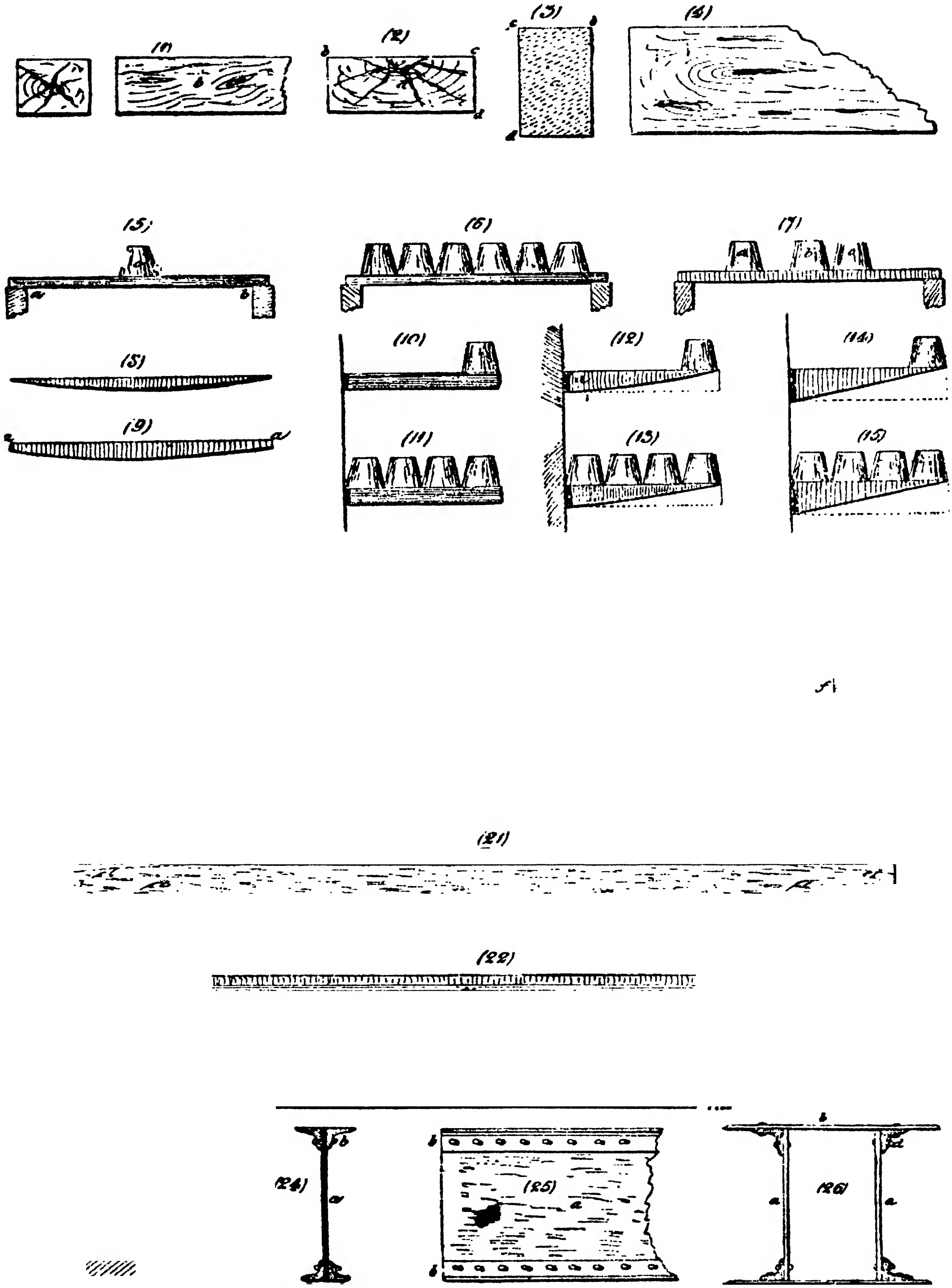


FIG. 11.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THE TECHNICAL STUDENT'S INTRODUCTION TO THE GENERAL PRINCIPLES OF MECHANICS.

LAWS AFFECTING NATURAL PHENOMENA—MATTER AND MOTION.

CHAPTER XXXV.

Properties of Bodies—Porosity (*continued*).

THERE is to the thoughtful mind no circumstance connected with the wondrous accumulation of materials with which in the natural world we are surrounded, which gives rise to thoughts so suggestive of the Divine wisdom which has given them to man for his use, than this—namely, the exceedingly varied nature of those materials. And just as one farmer wishes rainy, another fair weather, each thinking only of his own purposes and views, so a mechanic in dealing with a given material placed at his command may wish to have it possessed only, or chiefly, of a characteristic or peculiarity suitable only for the purpose he has in view; while another mechanic may wish to have his material suited for his purpose, although that be altogether different from that of his neighbour. But such is the wide diversity in the characteristic peculiarity or peculiarities of materials, that the mechanic can always find one if not absolutely or precisely, still one practically or generally, suitable to the work he has to do. Now, with the accumulated knowledge derived from the labours of his predecessors, the mechanic as a rule can place his hand at once upon a material possessing the characteristic he desires. But in doing so we fear that it is not always that he thinks of what must have been the close observation and the patience with which it was displayed, and the long, long course of years—generations many—through which that was exercised, before man *found out* the materials which possessed the varying characteristics he required for his work. Even yet the scientific man is finding out new uses for old materials, and discovering almost daily that some which have been tossed aside as worthless possess a high value to man. And this peculiar characteristic or property of bodies or materials known as porosity has been of immense service to man, although it sometimes happens that a mechanic does get hold of a material in which he would much rather that this porosity was not present. We have alluded to the continuity of the passages or channels in materials. Thus, let us suppose the trunk of a tree, the fibres of which are so arranged in relation to each other that they may lie parallel to one another throughout their length in their normal condition—that is, where no defects as from disease causing hard knots, etc., etc., exist. But they do not lie close to, but at some distance from each other; the result of which is, that a series of channels, passages, or to use the Latin term for this last word, pores, are found extending from end to end of the tree. This condition or property in wood would seem at first sight to be antagonistic to the ordinary purposes of the mechanic, who desires, as a rule, the closest grained or the hardest and densest wood he can obtain. But, as has been well remarked by a thoughtful observer, "nature is always compensatory": if she takes away with one hand, she gives something in return as freely with the other. Thus this property of porosity—passaged or channelled—is taken advantage of in many ways by the mechanic, and proves a powerful auxiliary in many of his operations. We can only refer to one or two examples of this—the first of which is the well-known process of preserving wood, by impregnating it with certain preservative substances, as salts, oils or tars. This impregnation consists essentially in the filling of the pores of the wood with those preserving fluids. If there were no continuity in the pores or passages, it is obvious that we could only affect the outside and part only of the inside of the mass of timber to be preserved. But by virtue of its porosity every part of the wood can be reached and placed under the influence of the preserving substance. So complete is the continuity of the pores in longitudinal channels that one well-known process of preserving timber depends wholly upon this property for its successful operation. In it the preserving liquid is applied under pressure at one end of the tree or log, and it flows through the passages till it reaches the other end, thus filling the pores throughout their length. By taking advantage of this principle of pressure the process of wood preservation is made much quicker than if the preserving liquid was allowed to be taken up naturally by the wood, if dipped into it, or if applied to one end and allowed to flow through it as best it could.

Properties of Bodies—Porosity (*continued*).

We have considered the passages or pores as being formed by the fibres of the timber lying apart from each other; these fibres thus represent what we popularly term the solid parts of the timber. And in one sense, therefore, they are really the timber, all the other parts being but literally spaces or vacuities. The mere filling up, therefore, of the pores with a preserving substance would appear to have the effect only of an outward application to the solid parts—that is, the fibres; and that until the interior of the fibres could be reached by it, the timber could not be said to be wholly acted upon by the preserving substance, for, as we have seen, the fibres really constituted the timber proper. Now, the interior or inner solid part of the fibres is reached by virtue of the same property of porosity, for though in one sense solid, the fibres are themselves made up of solid parts separated by pores or passages. And if we conceive

a fibre to be itself made up of a series of rings—just as an exogenous tree is made up of rings (we exclude the consideration of endogenous trees or plants, which have the central part pith only, and not what we call wood at all)—we can imagine how, though each ring has fewer pores or passages in it as it approaches the centre, still even the innermost ring will have its pores, however minute. This property of porosity—passaged or channelled formation or structure—is so prevalent throughout materials, each solid part within or enclosed by another solid part having its own individual pores, that it has been somewhat jocularly said that there is really no solid matter existing, or but so little of it that what there is of it in the whole globe itself might be compressed or squeezed into the form of a good-sized cricket ball. This, like all other exaggerated or paradoxical statements, contains, however, a truth; and is but another mode of expressing what we have elsewhere shown to be a mechanical or physical axiom —namely, that all the established or received properties of bodies are only relative, not absolute: thus, what we term solid is only that amount or degree of solidity which is due to or arises from the connection in which the body or material is placed at the time. Thus, we take a block of wood—say of oak—and we say that it is solid, certainly very much more so than a similarly solid or shaped block of white or yellow pine. We know almost intuitively that this is so; that is, we know that the oak will resist the blow of a hammer better than the pine, the latter being indented, while the former scarcely shows the hammer mark. Yet the oak is only relatively solid, for we can by mechanical pressure force the oak block into a smaller space than it occupies in its natural or normal condition. And when so forced we pronounce, without any hesitation as to the truth of the statement, that the oak block is now much more solid than before. This compression (from the Latin word *pressum*, and this from *premo*, I squeeze or force together or press) or increased solidity (from the Latin *solidus*, firm), is obtained simply by reducing the section, so to say, of the pores or passages, and thus in proportion bringing the fibres or solid parts closer or nearer to each other. But the pores or passages still exist; so that if by some means we can force, so to say, the fibres apart from each other, we then in proportion to this force increase the distance between them, till we may again bring back the pores or passages to their original size. This force we can obtain by water or moisture. If, while the oak block is in its compressed state we insert or drive it into an aperture made in another material, we may be able to withdraw it with comparative ease. But if we allow the two to remain exposed in the open air, so that the oak block may imbibe (from the Latin *bibo*, I drink, and the prefix *im*, that is, *in* —I drink in) moisture from the atmosphere, or, as may be done more quickly, by pouring water from time into time into the oak block, the pores will get refilled, and the fibres or solid parts receding from their compressed condition will necessarily increase the bulk of the block. It will now be no longer an easy thing to withdraw the block from the aperture in which it has been placed in the other material, the increased size giving it a much firmer "grip" (this is from an Old English word *griopan*, to seize or lay hold of) of the surface of the aperture. This swelling out or increase of bulk of timber is accompanied with the exertion of such a force that if the block in which the aperture is cut is not of great strength, such as stone, the force may be sufficient to split or break it asunder. This property of porosity places within the reach of the mechanic various methods by which he can alter their condition in relation to what is termed solidity, in a variety of ways very useful. And the power, so to say, which it gives him, by which a return to their original condition, or by which the property converse to or the opposite of compression, namely, of swelling out or increasing the bulk of certain substances, is also of utility to him in many of his operations. A striking illustration of the force, so to call it, placed at his command in virtue of this property of materials, is found in the case of a rope made of fibrous materials, as hemp, which we suppose to be what in ordinary language is said to be perfectly dry. In relation to which property of dryness it is well here to remind the student that it is the same as with other properties of bodies: the dryness is not absolute or perfect, but only relative; for substances which we pronounce dry, concluding that they must under the circumstances—such as a piece of wood which had lain over the shield or hood of a smithy fire for very many years—be dry, yet are found to contain moisture after all, and this is very appreciable. We refer again to the point, for it carries with it considerations which are too often overlooked —of great importance to the mechanic. In wetting the dry rope referred to above in virtue of its porosity, a certain portion of water is absorbed or imbibed. This, by filling the pores or passages squeezed together or closed by the contraction of the fibres as they dried, causes the rope to increase in diameter or to swell out. At first sight this would appear to be the only result of the wetting of the rope, the swelling being confined only to the parts wetted. But if the young student will think the matter out, he will perceive that the effect of the increase of the diameter of any part of the rope is the pulling up, so to say, of its fibres at that part, in rising or swelling outwards; this in relation to the core or centre of the rope is a vertical rising; but as the fibres rise vertically, they drag along the connected

fibres on each side, and this longitudinally, so that there is an actual shortening of the rope throughout its whole length, and this is accompanied by or is the cause of great contractile power or force, capable of raising or moving heavy weights. The contraction and expansion of certain materials in virtue of their porosity is a subject of very great importance to the practical mechanic, heat and cold being the great agencies. Those terms are, as we have shown in treating of repulsion, again purely relative: a body which is considered cold may be warm or hot as compared with another body. As a rule, the substances or materials which are of vegetable or wood origin are those which are more distinguished by porosity than minerals; and minerals, as stone, more than metals, as iron. But the young reader must not conceive of metals as being bodies wholly without this property: we have seen that gold, which we should pronounce to be absolutely "dense," or without pores, possesses them, so that water can be forced through a mass of it; and we have seen how the character of a metal, such as iron, is very much dependent upon the polarity of its molecules or its crystallisation, and that this cannot take place without the formation of pores, however minute they may be. And the practical man knows but too well, and to his cost, that by the defects of a process or the presence of some substance he can, even in that closest of all our useful metals—steel, create, so to say, an artificial porosity, which he would very gladly indeed dispense with.

Properties of Bodies.—Density.

In the last paragraph we have, in relation to the porosity of certain materials, used a word which we have marked with inverted commas; and from the sense in which it is there used the young student will understand that the term "dense" is used to distinguish a property of materials the opposite of porous. Here, as in other cases, the very root or derivation of the words "dense," "density," throws light upon what they mean. They are derived from the Latin verb *denseo*, I press together, I thicken—*densitas*, thickness—that is, the particles or molecules are more thickly disposed in a certain space in one body than they are in another body. If so, they must be closer together or nearer to each other than if they were, so to say, spread over or made to fill or occupy a larger space. We can obtain a very good illustration of the term dense, in this relation of particles being thickly placed together in a given space, in the case of a regiment of soldiers spread out over a large extent of ground in open or skirmishing order, and the same regiment massed into the "solid square" —which, the distinguishing feature of British army battles, has so often rolled back the tide of battle and resisted the terrible and oft-repeated assaults of the bravest and the best of foreign troops. Here we at once say that we have in the square a dense body of men; just as we use the same expression of a crowd of people assembled in a large hall, who are said to be "thickly" crowded together, yet who, dispersed over the surface of a very large field, would no longer constitute a dense or thickly crowded mass, but what in common language would be said to be a number of people thinly congregated or spread out over a large area. Here we see that the property of density is entirely relative. We have precisely the same number of particles—so to call each member of the crowd or each soldier of the regiment; but in the one condition of circumstances we have a "thin," in the other a "thick," or dense (bearing in mind the derivation of the word we have given) disposition of the particles. In applying these relative terms, thick and thin disposition of the particles, to the case of substances or bodies with which the mechanic has to deal in his daily work, the name of "porosity" is given to the thin disposition, that of "density" to the thick disposition. Thus, referring to our supposed case when illustrating porosity, the particles represented by the squares are kept apart or placed in relation to each other by their polarity, leaving spaces between them which we may suppose to be represented by black squares. If we suppose that the squares—particles—are forced or squeezed by a strong external pressure, so that part of their substance passes into the vacant spaces, we shall have those spaces just so much the less as there has been much or little of the solid parts of the squares forced into them. In this condition we see at once that the particles must be closer together, and that more of them can be made to occupy the same space—that is, lie more thickly together; in other words, we say that the body, made up of an aggregate of particles—squares—is more "dense" than the body in its original condition, with its open or vacant spaces as if in black squares. The maximum of density in the case here supposed would be when the particles were so closely squeezed together that the whole of the vacant or black spaces would disappear. But this maximum of density, or apparently complete doing away with the porosity of the mass, would still be relative. For, as we have shown in a preceding paragraph, what would be termed solid bodies are only relatively solid; since we can in several ways and in numerous bodies or substances prove, by demonstration which can be seen and felt, that the polarity of their atoms give spaces, or what we popularly term vacuities, precisely as we have supposed to be represented by dark squares. So that the maximum of density would not in reality be reached by the mere disappearance of the black spaces or pores, brought about by squeezing together the particles till they lay in close contact with each other.

THE STEEL MAKER.

THE DETAILS OF HIS WORK—THE PRINCIPLES OF ITS PROCESSES—THE QUALITIES AND CHARACTERISTICS OF ITS PRODUCTS.

CHAPTER XVI.

The Thomas-Gilchrist Process of Dephosphorising Iron Ores; otherwise the Basic Process.

At conclusion of last chapter we remarked that in the history of important inventions or discoveries progress in improvement is found, as a rule, to be made by gradual steps, and that often the inventor or discoverer is astonished when he looks back at what was the initial position which his discovery or machine at first took. But to some men is given the great gift not merely to grasp the general principle of a discovery, seeing what it can do now, but to take in, as it were intuitively, a clear conception of what it is capable of doing hereafter. They occupy, in virtue of this gift, possessed by few at the very first, such a commanding point that they see all around them while others are but groping their way in the lower regions of darkness and doubt. Humanly speaking, the career of the Thomas-Gilchrist process would have been very different from that which is now apparently before it had it not had the singular good fortune to meet with one possessed of the great gift above alluded to, held by so few, and of which it might be said so wished for by all. So far as their respective histories are concerned, there are some points of comparison more or less striking and suggestive between the history of the Bessemer and that of the Thomas-Gilchrist process. One feature distinguishes both—namely, that no one seemed at first—indeed, one may say for a long time—to have had the ability not merely to grasp the fact as a fact that either the one or the other had in it the elements of a change which would be equivalent to a revolution in metallurgical practice; but far below this clear, and as we might call it prophetic, foresight—not even to guess at or conjecture that the processes might be important. So far from this having been done—at least, if in isolated cases it was done, it was not made public—both processes were at first received with indifference, and at the best with that courteous incredulity which, while it refrains from open sneering and expression of ridicule, is just as operative in retarding the progress of a new process or invention as more active and less scrupulous opposition. The history of the early stages of the Bessemer process—one which, read by the light of its subsequent successes, was as brilliant from a scientific and mechanical standpoint as they were powerful in creating a "potentiality of wealth beyond the dreams of avarice"—might well have taught the world of practical men a lesson of some value. But, as history is said to repeat itself, so also do the peculiarities of human nature. These can never be eliminated from men, and they work to-day as they will work to-morrow, as they did yesterday; and not always in favour—too often, indeed, quite the contrary—of their true interests. The lesson of warning which the iron trade had received in connection with the Bessemer process—that much time, which to business men is simply money, would have been saved had practical men devoted as much pains and labour to see what the process was probably capable of doing, as they did unfortunately for themselves, and the nation devoted to prove, or rather to try to prove, that it was incapable of doing anything at all—was thrown away. For the succeeding great invention or discovery of Thomas and Gilchrist met with a fate somewhat similar. This striking difference, and it is suggestive of sundry practical thoughts, did exist between them. Somehow or another the announcement of Sir Henry Bessemer fell, so to say, amongst the iron men like a bombshell falls in the midst of a garrison or fighting party in the trenches; or, to use another simile—perhaps under the actual circumstances as they at the time existed more appropriate—the statements of Sir Henry Bessemer, and the fulness and freeness of his assertions, acted with the iron trade precisely as we find the waving of a red flag acts in the face of a rampant bull. Sir Henry was met with a perfect storm of refutation, of invective, and in not a few instances of scorn and sneering, and in a few with that treatment which verges upon if it be not quite injustice and wrong, and which has its rise in decided personal dislike, or a fear on the part of some at least, that their trade will be imperilled if not destroyed. The ancient cry heard in the streets of Ephesus is not altogether unknown in our modern cities. Fortunate it was for Sir Henry Bessemer himself—fortunate for the nation, still more fortunate for the very men who treated his proposals with contempt, or, worse still, assailed him on personal points—that he was made of the "sterner stuff than women are"; and knowing that he had, to use a graphic phrase, "got hold of the right end of the stick," he wielded it not only with courage, but with such vigour, tact, and skill, that he soon routed the opponents to his brilliant discovery and the mechanical means by which he made that discovery practically available.

The reception of the Thomas-Gilchrist process by the trade, and indeed by scientific men more or less directly interested in its progress—was altogether different from that of the Bessemer. No doubt, like the latter, no one seemed to have had even the remotest conception of the capabilities of the process. The youthful discoverers would only have been too glad to have had the announcement of their great discovery met by even a tithe of the active oppo-

sition which assailed the Bessemer process. In the "hurly-burly of the conflict," if they had received hard blows, they at least would have had the chance of giving in return blows as hard—indeed, harder, as they had the truths of facts on their side. But what chance of victory has one, or even of making a "drawn battle," if, while ready armed and with the courage to fight, the enemy will not fight—nay, will not even put in an appearance on the fighting ground? Galling enough, surely, is it for one ready and eager to decide his cause in open combat to find no enemy opposing him; still more galling to be told that the enemy does not think him worthy of any notice at all, far less considers him as "foeman worthy of *his* steel." Of the two it is not only infinitely harder to bear, but it is, in fact, more prejudicial to the interests of a new discovery or invention, for it to be received with contemptible indifference, than to have an opposition which is even distinguished by all those disagreeable elements which some men have the unhappy knack of introducing into the discussion of a purely scientific question. Opposition, no matter how conducted, acts like a storm of wind in the material universe: if it knocks down some houses and levels trees, at least it clears the air from fogs and mists, so that other houses and trees can be seen. Opposition is positive in its effects, and productive of progress in some direction; indifference pure and simple wholly negative and fatal to progress. And this was the fate of the Thomas-Gilchrist process at its first announcement.

Following upon such experiments as the comparatively limited facilities placed at their disposal permitted them to carry out, and which, although like the majority of past experiments made with any new thing, not in every respect successful, were yet fully and distinctly corroborative of the deductions of the theory upon which the process was based—Messrs. Thomas and Gilchrist prepared a paper descriptive of its general features. This was the paper, so often alluded to in the history of the process, which was read at the autumn meeting of the Iron and Steel Institute, held at Paris in 1876. So little interest did the reading of this paper excite, so trifling the hold its proposition took upon the minds of those who heard it, so few seemed to form any conception that these proposals contained at least the germ of something useful—so thoroughly, in short, was indifference manifested in the matter—that the paper was partially relegated to the pigeon-holes of the Institute.

But what the Institute in its corporative capacity, and what the large body of men in the iron worlds outside, in this country and elsewhere, failed to grasp, one of its members had the practical and scientific knowledge and the far-seeing business capacity to take thorough "grip" of. This was Mr. E. Winsor Richards, the able manager of the world-wide known and gigantic establishment of Bolckow, Vaughan & Co., of the Eston iron works, near Middlesbrough. If Mr. Richards did not—although we conjecture he did—take in a clear conception of the true potentiality for good of the new process, he did what so few men have the ability, indeed common-sense prudence to do, at the least deem it worthy of consideration, This, given to it in a most rigid way, led him to recommend to his Company a trial of it. Thoroughly appreciating his ability and the sterling worth of his character as a conscientious man, only interested in their interest, the Company wisely requested Mr. Richards to proceed with the trials. Mr. Richards knew that he had difficulties to overcome before the process could be an economical and therefore a commercial success. This much, indeed, he had learned from such scanty results as could be obtained from the preliminary trials made at the Blaenevan iron works, and at the still more celebrated works at Dowlais. But backed as Mr. Richards was by the high confidence reposed in him by his Company, and, what was more to the purpose so far as the means of working were concerned, the princely revenues of its directors, he was not the man who once "having put his hand to the plough" was likely to turn back. Like Napoleon—history applies this name to one only of this family—Mr. Richards had no such word as "impossibility" in his vocabulary: with him also a "difficulty" was a thing only to be overcome. And what the difficulties were are best known to those who, like the writer of these lines, know "something at least" of the money expended in overcoming them,—money which, when added up, amounted to what would be a most ample fortune. It may well enough and reasonably be conjectured that, had it not been for the work done by the Bolckow, Vaughan & Co. establishment, through the active agency, the mechanical skill and scientific attainments of their engineer, Mr. E. Winsor Richards, the Thomas-Gilchrist process would not have been at that stage of a successful career which we know it to have now reached. And whether we consider the circumstance that the Company had not only ample means at their disposal, but had such faith in their manager as the dispenser of it with the object in view, or on the other hand the ability of Mr. Richards, the fact remains that the public at large are the true gainers by this "happy combination of fortuitous circumstances." To a combination of this kind the Thomas-Gilchrist process, now a success, and bidding fair to bring about a perfect revolution in the practice of iron and mild steel making, was indebted.

THE FACTORY OR MILL HAND AS A TECHNICAL WORKER.

THE ORGANISATION, GENERAL DUTIES, AND SPECIAL WORK OF THE STAFF OF FACTORIES FOR THE PRODUCTION OF SPUN AND WOVEN GOODS—THAT IS, "YARN" AND "CLOTH"—AND THOSE CHIEFLY IN COTTON AND WOOL.—GENERAL DESCRIPTION OF THE VARIOUS PROCESSES OF MANUFACTURE.

CHAPTER XIX.

AT end of last chapter we stated that the sizing of the yarn and the subsequent drying of it go on together. After the sizing and drying, the make of the size and the perfection of the drying enables the manufacturer to lay them on one side for a time, if not immediately required, and this can be done without proving at all detrimental to it in the process of weaving. The perfection to which the preparation of size has been brought to insure the keeping of the yarn after sizing for such an indefinite period is a marked feature of the trade.

Woollen Factories.—Mill Management.

In last chapter we brought the work of the cotton mill or factory up to that point in which the fibre is converted into cloth or calico, which is its finished condition ready for market. We have next to take up the work done in a woollen factory, which embraces the manufacture of worsted used in a variety of fabrics, as well as the important department of woollen cloths, or what are so familiarly known as "broadcloths" or "West of England cloths," in connection with which there is much that is practically interesting from a technical point of view. Before commencing to describe this most important department of the technical work of textile manufactures, we have, however, to glance at several parts connected with mill management not yet embraced in preceding departments, and which chiefly concern the master or proprietor or his manager, and their assistants.

It is of the utmost importance to have a spinning mill well arranged (*i.e.* a well built and convenient mill), to have the machinery of the most improved make for the kind of work which it is intended to produce, and to have it so planned that every point can be secured with the utmost degree of economy and efficiency, thus making the business speculation thoroughly successful. No one would be so unwise as to commence a business either of spinning, manufacturing, or of buying or selling articles already manufactured, with some latent doubt on his mind that it would be a failure. This sort of way of entering on a business seldom occurs, and to an outsider even it would appear foolish in the extreme. To secure success one must not only desire but be determined that he shall obtain success. We are all less or more sanguine of success in any undertaking which our fancy leads us to speculate in. It is mainly the hope which helps us and really spurs us on to use that energy which is absolutely necessary to insure success in business of any description. Although this success in business will, as a rule, be secured if we are diligent and prudent in our proceedings and alert, so to say, in our movements, still there are different reasons why one may be successful, and others why another may be unsuccessful in business. Without giving—which in one sense it would not be possible to do—all reasons for success, we may state one or two, so that the youthful reader may reflect upon them, and thus see in them others which may go to secure the desired result, sometimes we say fortune pours in upon some men in their business undertakings, and so it apparently does. But fortune should not be looked upon as a providence forcing, as it were, this good luck upon a man without any forethought or care and judgment on his part. Such a man is said to be "far-seeing," as it is termed—*i.e.*, by the power of thought weighing and considering the circumstances surrounding the sphere of his intended action, his perceptive faculties being brighter than his neighbours', and thus enabling him to make choice of a situation more suitable for his enterprise. And not only this, but it is of the utmost importance for the man of business to carry out the old proverb, "God helps them that help themselves," and this is the second step to success. This means watchful care, economy, not only in his business, but in his household affairs. A man to be sure of success should, in addition to the above, have not only a good practical knowledge of his special work, but should feel that his energies and talent to make that work available must be all happily combined. It very often happens that a man who enters on a business speculation may not be possessed of any practical knowledge of its work, and yet be very successful in it. But in such cases it is mostly found that there is a degree of shrewdness about him, and in this way he deliberates upon the best mode of carrying out his project, and with his natural ability of distinguishing the tact and ability of his fellow-man he thus makes choice of a suitable one to manage his business for him, taking care, however, to keep what is so well known as "the whip hand" of all. He distinguishes in this manager not only an ability for such a position, but he judges in him further that he is one who would take a pride in being in such a station; and therefore it is only natural that such a man would exert himself to excel in his undertaking. Other illustrations might be added to prove how some men in their undertakings succeed. We hope the few we have given will give the youthful reader a line of thought by which he may guide himself and prove to himself the importance of thinking and of "looking before he leaps." As to the un-

successful we might, as a rule, say that the opposite of all this holds true. But we would not, however, be altogether uncharitable to the unfortunate, as our experience in life has proved that one may work hard to deserve success and yet not obtain it. Still the above remarks on the successful will hold good. There is another proverb which is common to us all, and not only common, but in the sense of being somewhat rough is a very true one—"Money makes the mare to go." We believe that the want of success in a great number of cases is the want of more money or "capital." The want of sufficient money is a bitter and an unprofitable experience. We would not say that after all being a little short of money is not in some instances an incentive to activity and perseverance, and during this activity and perseverance it is, or should be, coupled with one other all-important step to success—that is, economy at home and in business. But where money is already plentiful there appears less call for such care, either at home or abroad; yet in such cases a lower degree of success must needs follow.

How generally do we hear the expression that such an one has made a fortune in so short a time!—but now he who made his fortune in so short a time would without hesitation say he could not do so well now—*i.e.*, he could not increase his business or lay up money in the way he had done in former times; this may be accounted for in the want of the usual economy. We cannot spend money and still have it. To show more clearly that our remarks are based upon facts, we know of men in business who have commenced with the smallest of means (almost no means) who are now "piling their cash up in heaps," either in increasing their business or purchasing some profitable property. This is no better known to us than to all who are observant of business men known to them. We all may learn many of the real facts of life by observation: this kind of education is by no means to be despised.

As we all like to understand a man's motives, etc., as they are, and to watch the habits of men's lives and the result of them, we become more and more educated into the realities of business society with which we must daily be associated. Our object is to try to help our young readers to think out the questions on subjects as they present themselves in every-day life. It is known to all thinking men that it is much easier to be satisfied with surface teaching and surface reading, but with the truly wise and prudent man such superficial education will not satisfy him. We should hope that more of the thinking quality of man's real nature will be brought to light as education advances. The truest education enables a man to distinguish between truth and falsehood—*i.e.*, between right and wrong principles. No man is more gratified than when he can discern for himself the real facts of a case. He is all the better thus fitted as an employer, foreman, manager, or as a workman, let his class of work be what it may, simple or complicated. He will have greater interest in his occupation, a greater interest in producing the best result under the circumstances, and it will tend to bring out his better faculties.

This state of mind would give real pleasure to the operative, and his labour would not appear so irksome to him. We would not say that such a millennium is to be looked for in every individual. The capacity for education is not so prominent in every one as to displace the great selfishness which rules amongst so many of us. We hope that each succeeding generation will have less of this element to contend with.

Were work looked at as a necessity for the health of the body as well as for that of the mind, we should all relish the opportunity of working. Had it not been of Divine providence that such was good and absolutely requisite for us, things to supply our needs would have been provided for us simultaneously. When we are engaged in something which is to our own gratification, we labour willingly, and if need be unceasingly: should that time come when we could for hire work for others as for ourselves, it would truly be a life worth living for in comparison to that of working in fear lest we do more for our employer than we think we receive back again in return.

Management of Mills (*continued*).

In all cotton mills, be they of what class they may (*i.e.* fine or coarse spinning mills), they have of course each a system of book-keeping. The systems adopted in connection with the workpeople must of necessity be of a very simple character, and must also very much resemble one another. In some mills most of their hands are paid by a special "indicator," or "clock" (in the card room or preparation room), and that registers the length of work, sliver or roving, which is produced, and the worker is paid accordingly (*i.e.* so much for each hank produced). Say that fifty hanks have been produced during the week (that represents a certain length), and for each hank the worker (called a "tenter") receives, say 3*d.*, that would be 12*s.* 6*d.* per week. The "tenters," however, as a rule, make more than that amount; but that is sufficiently near to give the idea. At the end of the week the "bookkeeper" or "overlooker" or manager goes round to each frame and takes the position of the "indicator," commonly called a "clock," by referring to the position of it as it was at the same time in the previous week; the difference is credited to the "tenter" or "minder." This clock or indicator principle is adopted in all coarse spinning mills, being much simpler than that

of weighing each set as it is taken off. A "set" represents what is called a "doffing." Doffing means the taking off full bobbins—*i.e.*, bobbins which are filled with cotton in the form of a "roving" or "sliver." And these empty bobbins are put in the place of those full ones as they are taken off, and this process is continued throughout the week. For the spinning rooms the book called the spinners' book account is kept: *i.e.*, the amounts of yarn (cops) which are spun are sent down to the room where the packing of such cops is carried on, and are there weighed. Some are paid by weight, and in most instances the weight is calculated by the "counts" of the yarn spun. "Counts" represent so many hanks in the pound—*i.e.*, eighty threads of one and a half yard each in length represent a "lea," and seven such "leas" represent a hank; and if forty of such hanks weigh one pound, the fineness or counts of the thread is called "forties." In like measure, if the set of cops which have been sent down weigh fifty pounds, then there would be two thousand hanks, and so each set doffed is entered in the spinner's book to the name of the spinner, if at hand-mule spinning. But if the yarn is from a self-acting mule the weight is entered opposite to the "minder's" name, and in addition to the name the number of the mules is also entered; and at the day for making up the wages, the weights of the sets (yarn brought down) are all added up to a total and then multiplied by the counts of the yarn; thus the production in hanks is made out. The process is extremely simple. The principle of paying by hank or hanks is mostly adopted in the coarser spinning mills. The thoughtful reader will see the difference between the payment of wages in the "preparation room" and "card room" ("frame room"): in one case the operative is paid somewhat differently to that of the other operative, although both are paid by the hank. The reason why the difference exists will be soon understood. In the frame room the yarn is put upon very large bobbins, and the weighing of the work in such a case would require one or two extra hands to do it, even in an ordinary-sized mill, and so the clock system is adopted in the place of weighing the work as taken from the frames. It might be asked, why not adopt the "clock system" in spinning rooms (mules)? In the frame room the minders or working hands do not use any instruments—as keys, *i.e.* "screw keys" —such as would do and undo the fixing of the clocks; and the workers on frames being females, they perhaps may be less disposed, or have less mechanical disposition, to meddle with the mechanism of machinery than those who are engaged in the spinning room. The spinners or minders, being all male workers, their inclination is to interfere with and manage their own machinery, besides that the custom in the trade allows the spinner or minder to do little matters in the way of regulating anything which gets out of order in a mule, which is always requiring attention to keep in regular good working condition. Thus the mule spinner or minder is trusted as a matter of necessity to have instruments to do these trifling repairs; and it has often been found that where the system of spinning by the regulator or clock was used, it had ultimately to be abandoned on account of the worst disposed of the workers meddling with the indicator and making it represent a greater amount of work performed than could be found from the weight of yarn received from the mules—hence the system of weighing the work, and after that transferring the weight into hanks. In the case of the "frame" worker, she is paid by the length, as we may say, of work run upon one bobbin, whereby the difference of payment arises in the arrangement of paying in one case by the hank per spindle, and in the other by the hanks produced from all the spindles. The difference between the two is simply a matter of calculation as to the price; this is self-evident, and needs no more illustrating. To lay down in this paper a plan or system of keeping such books would be in great part useless, as it would at once be seen, even by a schoolboy, that the only way to keep an account of work produced by one man must of necessity be to keep it to itself, and that each production from the same man must be kept to itself, and that the weight of yarn each time brought into the warehouse from the same person must be entered one under another, so that they can be conveniently added up at the end of the week into one lump sum (which is generally fixed for Thursday night), and this for the sake of the bookkeeper in the office having sufficient time to enter all names, weights, etc., of the workpeople, and thus be ready for payment on the Saturday (say at one o'clock).

Management of Mills (*continued*).

The next matter with regard to workpeople is "timekeeping" for day hands—*i.e.*, that class of hands who are paid at so much the hour, or so much the day or week. Some responsible person—the bookkeeper, or the carder (or overlooker) in each department—is intrusted to keep a small memorandum book and enter the time made by what is termed "day hands," and on Thursday afternoon or Friday morning he takes his time-book into the office for the bookkeeper in the general office to copy the time made by each "day-work" hand. In most mills, where a minor clerk is kept, this often devolves upon him, and he thus walks through each room immediately after the engine is started, and should he not be able to find all the persons at work according to names of the "day hands" which are in his book, a remark is made.

by him by which he can at the close of the week deduct the amount of time which is lost. This mode of time-keeping does not vary so much in form, as it is so simple that to give a formula here would be lengthening out this paper to an unnecessary length without any corresponding gain. We may say that the principal man, who is termed the "manager," and who is intrusted with everything inside of the mill, being the one who is independent of all the subordinate servants (as bookkeepers or overlookers), should in his general survey spy out any irregularities in the attendance of the "hands" (workpeople), and so make a note in his private memoranda, and at the end of the week take a survey of the entries in the wage book, so as to prevent carelessness on the part of those whose business is to see that correct time is given in to the office. This duty, which is truly a part of a manager's government or superintendence, helps largely to stimulate the inferior (though trusted) servants to be watchful and correct in the duties they have to perform. Men of a low type of mind, and those whose habits of life are somewhat extravagant, are at times tempted to do that which under the circumstances would be far from them. It would appear useless to some to refer to anything of the kind, as they might say, Where could any advantage accrue by any irregularity in time-keeping? Let it suffice as a warning in connection with a duty. The above remarks cannot be in any degree offensive to the honestly disposed; but in treating upon systems (and having had thirty years of management and experience in these matters we may be pardoned for saying things which to the more experienced mind might appear ridiculous) we hope nothing may occur but that which is right; nevertheless, a word in season may be a preventive of occurrences of an unpleasant nature. "Prevention is better than cure." We hope our readers—we mean those of them who have had little or no experience in this way—may be a little charitably disposed at all times to those of longer experience, and that the old saying "look before you leap" may be uppermost at the time, and thus they may conclude that any remarks which are made in this paper are really made with no other intention than that of serving a practically useful purpose. We are well aware that those of long experience in business matters will at once see the force of our remarks, and will not charge us with wishing to say more than what experience warrants.

This leads us now to refer to the duties in general of the clerks in the office of the mill—*i.e.*, the place where all the books are kept. The office is of course provided with what is called a set of books, by which all entries of goods received and also of goods delivered are kept. The book which is used for goods received is called the "received book," and in this book every article is entered which enters the mill doors, be it for whatever purpose it may. This book is of infinite value, whether the man who received the goods be still in the employment, or far away; the articles from every firm as received are entered in full, so that when an invoice is presented each article can be checked, and thus the invoice be found to be correct or otherwise. As to the price charged for each article in the invoice, that is but seldom entered in the delivery note, and therefore the knowledge and discretion of the manager, master, or bookkeeper, has to be brought into request. Some of them would almost know to a certainty whether the charges were correct, from their general experience. Another book which is kept is called a "delivery book," in which all goods (nay, we may say articles of every kind) are entered; from this book the "day book" is formed. But here we may say that this delivery book has for its especial object perhaps that of receiving the signature of the individual who received the goods; some again use as a delivery book one in which there is a copy of that which is given to the person receiving the goods, he leaving his signature on the copy of the corresponding note to that which he takes with him. A delivery book of this kind is on a very simple plan, and is also useful for the bookkeeper to copy into his "day book," where he enters the prices to each article into it, and from which he makes out his invoices of the goods delivered.

This does not complete the business of the bookkeeping in a mill, any more than that in any other business. Another book called a "ledger" is kept, and this book when properly kept entered up shows at a glance the amount of money which stands to the credit or debit of any one; and when any account is paid off the clerk enters the sum in the ledger and rules it off. There is a clear page of his account until a further transaction take place. It is necessary that this book should have an index attached to it. This index is systematically arranged, and, it being a long one, the alphabet can be placed so that the letters follow in order (*i.e.* alphabetically), beginning with A and ending with Z. Each leaf has a piece cut out sufficient to receive the letter. Suppose Thomas Johnson's account is to be found for any purpose whatever, the ledger-keeper or the principal at once refers to the index; and looking for J, and on the page of J, will be found Johnson, Thomas, the surname always being put the first in an index. There will be found opposite to Johnson, Thomas, a number of the page of the ledger, upon which, by referring to it, Thomas Johnson's account will be found.

THE BUILDING AND THE MACHINE DRAUGHTSMAN.

CHAPTER XXVI.

CONTINUING our description of the mode of finding the curve of a helical staircase commenced in last chapter, and illustrated in fig. 3, Plate CLXXXV., we proceed to state that the helical curve line produced by the point of the steps next the outer circle in A A starts from *i*. To find the line produced by the inner ends of the steps at small circle B, proceed as follows. From the various points in circle B produced by the ends of the radial line from points 1, 2, 3, etc., draw verticals; the point *k* will be No. 1, the next point No. 2, and so on. Where the verticals cut, the correspondingly numbered horizontals from *g* will give the points through which the curve is drawn. The starting point *o* on base line *c d* in C C is obtained by drawing a vertical from point *p* in inner circle B in A A. The curve of inner ends of steps cuts that of the outer ends as at the point *q*, and it terminates near F. The spaces between these, as at D and E, are concave or hollow, and if the drawing of the staircase was finished, the steps would be shown. Lines continued from points on the line *g* would in fact give the steps. The part at F is convex.

Delineation of Square-Threaded Screws.

We now come to illustrate the application of the principle of the projection of helical surfaces in the projection of screws, square-threaded and angular-threaded.

Let *a b c*, fig. 1, Plate CXX., be a circle, the diameter of which is equal to that of the outside of the screw. Through the centre *e* draw a line *e f*, and on this, at any convenient point above the circle, the line *g h*. Draw the diameter *b a*, and from centre *e* describe a circle concentric to the larger circle, the diameter of circle *i j* being equal to the diameter of the inside of screw. From the points *b*, *j*, *a* and *i*, draw, parallel to *e f*, the lines *a k*, *i l*, *j m*, and *b n*; these will give the boundary lines in the elevation of the outside and inside of the screw, the distance, as *b j* or *a i*, being equal to the depth or projection of the screw from the central bar or body of it, round which the thread is cut. With the distance *a i* or *b j* set off on the centre line *e f*, from point *o*, a series of distances, as *o p*, *q r*, *s t*, *u v*, and through these draw lines parallel to *g h*, as *w p x*, *y q z*, *a′ r b′*, *c′ t d′*. The parts, as that between *g h z b′ q w*, give the depth of one thread, the sides of which are bounded by right lines, as *g w*, *z b′*, these points being joined by curved lines, as *g e′*, *f′ g*, *p j′*, *i z*, which are found by the following operation. Divide the semicircle *a* 4 *b* into any number of equal parts, as eight in the diagram. From these points draw, parallel to *e f*, lines as in the diagram, as 2 *f*, 3 *m*, etc. Divide the distances *g w*, *x z* each into four equal parts, and through the points, as 1′, 2′, 3′, draw lines parallel to *g h*, as 1′ 1′, 2′ 2′, 3′ 3′. The intersection of the line 1, drawn from semicircle *a* 4 *b*, with the line 1′ 1′ on the line *g w*, will give a point *e*; the line 2, with 2′ 2′, a point *f′*; the line 3, with 3′ 3, a point *g′*. The intersection of the line 7, from the semicircle *a b* 4, with the line 3′ 3′ on *x z*, will give a point *h*. The intersections of the lines 6 and 5 with lines 2′ 2′, 1′ 1′, will give points *i′* and *j′*. Through the points *e′*, *f′*, *g*, *p*, *j′*, *i*, *h*, draw by hand a curved line, terminating at *g* and *z*. Divide the distances *w y*, *z b′* each into four equal parts, and through the points draw lines parallel to *g h* as before. The intersections of these with the vertical lines drawn from the points 1, 2, 3, 4, 5, 6 and 7, on the semicircle *a b* 4, will give a series of points, as *k′*, *l′*, *m′*, *n′*, *o′* and *p′*, through which a curve is to be drawn by hand, terminating at the points *w* and *v′*. The boundary lines of upper and lower edges of the first thread are thus put in. The same operation repeated will give the lines of the second thread, *y a′*, *d′ d′*, and of the third, *c′ c′* and *q′ q′*. By examining the figure the draughtsman will perceive that the ends of the threads are joined with curved lines, as A A to the central part B B B. These go downwards to the left hand and upwards to the right of the screw, as will be seen by inspecting the figure. These curved parts are put in exactly in the same way as the other curves, being drawn through points obtained by the intersection of the horizontal lines, as 3′ 3′ on *w y*, 1 2, etc., in the semicircle *a b c*. Thus the curve A between the points *y* and *w* is drawn through the points as shown; but the full line stops at the vertical line, the boundary line of the central bar or core of the screw. The curve A between the points *b′* and *d′* is drawn through the points given by the intersection of the lines at *v′*, *w′* and *x*, but stops also in full line at *w′ z′*, the side of the central core. But it will be observed that the under parts of the thread join the central core or bar by means of curved lines, those curves being below the thread on the left-hand side of the screw, and above it to the right-hand. These curves are obtained by the intersection of the horizontal lines, as 1′, 2′, 3′ on *g w*, with those vertical ones drawn from points found on the inner semicircle *i* 4″ *j*. This is divided into the same number of equal parts as the semicircle *a b c* (the division *i i j* will be most readily found by drawing from the centre *e* radial lines, as *e i*: these will cut *s i i j* in the required points, as 1″, etc.). Lines are drawn from the points on *i* 4 *j*, as 1″ 2″ 3″, etc., and these intersecting with the lines on *y w*, as 1′ 2′, give points through which the curve is drawn by hand. In like manner the reverse and corresponding curve *z′ q* is put in by drawing a curved

line through the points a'', b'', these points being found by the intersection of the vertical lines with the lines $3'$, $2'$ on the line $b\,z$. It will be observed that these curves all start from the lines at $a'b'$, $g\,h$, as at s' and 5^3. In order to clearly understand the relation which one part of the projection here given bears to another, and the principle upon which the whole depends, the pupil should most carefully study the projection as a whole before proceeding to project it for himself; and this projection he should make on a much larger scale than the space at his disposal admits of. The same remark applies to the projection of the angular screw now to follow, and indeed to all the other projections in this paper: the larger the scale, the more clearly seen are the intersections of the various lines on which the finding of the points required depends.

The diagram on fig. 1, Plate CXX., illustrates a method of putting in the curves of a screw of same length—*i.e.*, with several threads, without so many vertical and horizontal lines, which become confusing to the young draughtsman. Thus, on the first set of vertical and horizontal lines being obtained, as at $w\,g\,o\,p$ in fig. 1, Plate CXX., and $p\,x$, $z\,q$, it will only be necessary to mark off on the vertical centre line $e\,f$ the distances as $o\,p$, $q\,r$, $s\,t$, u and v, or as many as will be required for the number of threads to be delineated; drawing through these lines parallel to $g\,h$. Suppose the line $a\,b$, fig. 2, Plate CXX., to be one of these lines, and $a\,c$ to represent part of the bounding or exterior line of threads, as $a\,g\,c\,k$, fig. 1, Plate CXX. By means of the T-square set with edge coincident with the lines drawn from the points 1, 2, 3, 4, in the semicircle or plan of screw in fig. 1, Plate CXX., run the pencil—not touching or marking the paper—till the line, as $a\,b$, fig. 2, Plate CXX., is met with, and mark faintly yet distinctly the points in it d, c, f, g. Continue these vertically a short distance above $a\,b$, in faint yet distinct lines. Then, with one of the distances, as $g\,w$, fig. 1, Plate CXX., in the spring dividers, set off on vertical line at d one of those distances to h, on line e two to i, and on line f three to j. The point k will be equal to four of the distances, or equal to $b\,c$ or $g\,w$. By drawing a line through the points h, i, j, k, a curved line will be obtained equal to and which will coincide with the line $g\,e'f'\,g'\,p$ in fig. 1, Plate CXX. The points l and m, which give part of the curve at the upper side, are found in the same way, starting from the line $c\,m$. The part at A, fig. 1, Plate CXX., is shown in part in fig. 2, Plate CXX., where the point y and line $y\,z$ correspond to similar parts correspondingly lettered in fig. 1, Plate CXX.: $y\,a\,d$ being part of the bottom curved line of thread $y\,a'\,d\,d$ in fig. 2. The points a, d, being given, lines are drawn through these vertically, and extending below line $g\,z$. From this line, at points b, c, make r' equal to $b\,a$, and $c\,l$ to $c\,d$; and from g draw the curve $y\,r\,1\,l'$. This stops, however, at the line s'.

We may here point out how the methods described in last paragraph may be applied to copy any curved or irregular line, as the line $a\,b$ on the upper side of the line $a\,c$, fig. 2, Plate CXX. At any convenient number of points—the more numerous these are the better—draw vertical lines known as "ordinates," as at the points d, g and i. Suppose the curve $a\,b$ is to be drawn on the under side of $a\,c$, continue the ordinates for some distance below $a\,c$. Then set off distances $d\,c$, $g\,h$, $i\,j$, $c\,b$, to the points k, l, m and n. These will give points through which the curve required is drawn. It is obvious that this method is applicable to a line in the same position as $a\,b$.

Delineation of Angular-Threaded Screws.

In fig. 3, Plate CXX., we illustrate the method of delineating an angularly threaded screw. The principle of the operation for finding the curves is precisely that explained in connection with the square-threaded screws in fig. 1, Plate CXX., and the young draughtsman should have no difficulty in projecting the drawing from the description there given, and the following brief explanation of fig. 3, Plate CXX. The line $a\,b$ in the lower diagram marked A is the centre line of plan of the screw, C being the centre, and distances $a\,d$, $b\,e$, corresponding to the distance the edge or outside periphery of the angular parts project beyond the solid core or body of the screw. The two circles $a\,f\,b$, d 11 e, are each divided into the same number of equal parts, through which radial lines are drawn to the centre $c\,c$.

Let $a\,b$ in diagram B B, at top of fig. 3, Plate CXX., be the base line or commencement of the screw, parallel to $a\,b$ in lower diagram A A. From c in A A continue the radius $c\,f$ to c in B B. From point d in this set off distances, as $d\,e$, $d\,f$, to g and h, each of these being equal to the distance $a\,d$ or $e\,b$ in A A. Through points e, f, g and h draw lines parallel to $a\,b$, as $i\,j$, $k\,l$, $m\,n$, and $o\,p$; these give half the height or depth of a complete thread. From points a, d, e and b draw lines parallel to $c\,f$, and continue them to the diagram on B B, as $a\,o$, $b\,p$. The parts as $a\,i$, $j\,l$, are each to be divided into the same number of parts as the quadrants $a\,f$, $b\,f$ in A A are divided into—that is, four in the drawing. The intersection of "verticals" or ordinates drawn from points in the semicircles at A A drawn parallel to $c\,f$, with the "horizontals" drawn from points as in $a\,i$, $j\,l$, in B B, gives the points of the curve. Thus the intersection of line from point 1 in A A with first horizontal drawn in $a\,i$ gives the point 1 m; that of vertical from point 2 in A A with second horizontal in $a\,i$ in B B gives the point 2; of vertical from 3 in A A with third horizontal in

a i gives the point 3, and thus the points 4, 5, 6, and 7. Through these, beginning at point *a* and terminating at *l*, the first curve is drawn, which gives the highest or outside sharp edge of the thread. The curve of the bottom line of thread is formed by the intersection of the verticals from points 8, 9, 10, etc., in A A (in inner semicircle), with the horizontals drawn from the points *q*, *r*, *s*, *t*, giving points through which the curve *q* 8 9 10 11 12 13 14, and ending at *t*, is drawn. The outside lines of each thread are straight, forming the two sides of a triangle, as *a q*, *q k*.

Delineation of Mechanical Contrivances for Communicating and Changing the Direction of Motion.

We now come to the delineation and setting out of contrivances for changing the direction of motion, and of communicating this either in a regular or uniform or a changing, intermittent or interrupted motion. If a wheel or flat disc or a pulley be securely fixed—the technical term is "keyed on"—to a shaft, which by the power of the prime mover, be it a water-wheel, a windmill, or a steam engine, or other motor, the disc, wheel or pulley has the same number of revolutions as the shaft to which it is keyed. The reader will take note here that while the pulley, disc or wheel makes the same number of revolutions per minute as does the shaft to which it is secured, the velocity is not the same. Each point in the face of the disc has a greater velocity than the shaft, and that in proportion as the distance of the point from the centre of the shaft increases, the velocity being greatest at the edge or periphery of the disc. Hence the circumferential velocity of the disc—that is, the number of inches or feet passed through per minute—is greater than that passed through by any point in the circumference of the shaft itself. The young draughtsman should thoroughly understand this point, and be able to see the difference between the number of revolutions made by a disc wheel or pulley per minute and the number of feet or inches of space passed through in the same time. It is important that he should see this, as it lies at the root of much of his mechanical designing. A simple illustration will make the point of difference as stated above clear. Thus, let him suppose two concentric rings or circles to be drawn upon a large lawn, and a pole to be placed in the centre common to both. Let one ring be much larger than the other. He will see that if two boys be set to run at the same number of revolutions or runnings-round per hour of the two circles, the boy who has to go round the larger of the two will have to run just so much the faster to make the complete round or revolution in the *same time* as the boy running round the smaller circle; and the first boy would have passed through a much greater number of feet or yards than the second boy who was going round the smaller circle. Yet both boys would make the round or revolution only each in the same time.

A wheel or pulley fixed in a revolving shaft can only communicate motion to another wheel or pulley fixed in another shaft, but they can alter the speed of one another; a large toothed wheel "engaging" or "gearing" with a smaller or less diametered wheel giving a greater velocity or number of revolutions per minute to the shaft on which the small one is keyed. And the same holds good of the converse of this condition, where a small wheel drives a large one. And both cases apply equally to pulleys driven by belts, straps or ropes. But wheels and pulleys cannot alone "convert" or change the character of one kind of motion into motion of a different kind. The motion of driving wheels or pulleys being circular, and continuous for the time being, the motion also of the driven wheels or pulleys, to which they communicate their motion by teeth or friction, or by belts, straps or ropes, is also circular and also continuous for the time being.

Delineation of Contrivances Connected with Motion.—The Eccentric.

When the character of the motion is to be different, or one motion is to be, as the technical phrase is, "converted," other mechanical contrivances have to be employed. Thus, to change a continuous circular into a reciprocating rectilineal motion or movement, contrivances known as the "crank," the "eccentric," and the "cam," are employed. The exact character of the movements produced by those contrivances will be found elsewhere explained; we have here only to concern ourselves with the method of setting and delineating them, merely giving in a general way the mechanical peculiarities of their motion. In fig. 1, Plate CCXVII., we give an illustration of an "eccentric," one of the contrivances above named for changing continuous circular into reciprocating rectilineal motion. This forms an important part of the mechanism of a steam engine, the continuous circular motion of the main driving or crank shaft of which is changed into the alternate to-and-fro or reciprocating motion of the "slide valve," which regulates the admission of the steam to the upper and lower sides of the piston in the cylinder, and of the withdrawal of the steam through the "exhaust port" after it has worked the piston up and down or to and fro alternately. Whatever the "travel" of the slide valve in extent of rectilineal motion from one end of its movement to the other may be, this, or the "stroke" of the valve rod which moves the valve, is a distance corresponding to the distance of the centre of the eccentric or "eye" by which it is fixed to or "keyed on" the shaft from the true centre of the circular disc which forms the body of the eccentric.

Thus let *a b c d*, fig. 1, Plate CCXVII., be the disc forming the eccentric. If the eye or "centre" of this, by which it was passed over and secured to the shaft, were at the point *e*, which is the true centre of the disc considered as a disc only, it is obvious that, keyed on to the shaft, the disc would revolve at the same number of revolutions per minute, its circumference or line of periphery, as *a b c d*, being always in the same plane. But by placing the centre of the eye or working centre of the eccentric at the point *f*, an essentially different condition of matters would be brought into existence. Suppose the eccentric to be keyed firmly to the shaft, *f*, the end or cross-section of which is indicated by the cross-hatching lines, *e* being a cross-section of the "key." As the shaft *f* revolved it would carry the eccentric round with it; and assuming that the direction of the motion was in that of the arrow 1, when the shaft *f* had completed the first quarter of its complete revolution the point *c* or lowest part of the eccentric *a b c d* would be found at *g*, towards the right hand. The shaft *f* continuing to revolve in the direction of arrow 1, when it had completed half of its revolution the point *c* would be at *h*, having moved from *f* to *h*. The shaft still continuing to revolve, the eccentric *a b c d* would be carried round towards the left-hand side of the centre line *h c*, in the direction of the arrow 2; and on the shaft completing three-fourths of its revolution the point *c* would be at *i*, having moved from *h* to *i*. When the fourth and last part of the revolution of the shaft *f* was completed, the point *c* would have returned to its original position.

Delineation of Mechanical Contrivances connected with Motion.—The Cam or Heart-wheel.

The motion given by the eccentric to the piece or part of a machine which receives rectilineal motion from it—as the slide valve, for example, of the steam-engine already referred to—is not uniform throughout its travel or to-and-fro movement. This is, in fact, a varying movement—that is, its velocity is less at one part of its travel than at another—the velocity increasing during the first half of its travel or stroke, and decreasing during the second half of its stroke. Where the reciprocating rectilineal motion given by parts of machines having a continuous circular motion is required to be uniform throughout its whole stroke, the contrivance known as the "heart-wheel-shaped cam," termed otherwise and simply the "heart-wheel," is employed. This is illustrated in fig. 1, Plate CXXXIV. But before passing to the description of this, we show in fig. 1, Plate CCXVII., one form in which the eccentric is delineated. With the exception of very small sized eccentrics, the central part of the disc is cut out or formed with vacant or void spaces. This is done to save weight, and in no wise interferes with or lessens its strength. The parts taken out or left void assume greatly the form as at *j j j k k k* in fig. 1, Plate CCXVII. The two spaces are right and left, being divided by a "rib" or "feather," *l*, placed there to strengthen the central "web" or thinnest part of the disc, shown at *m m* in front elevation (central figure), and at *h* in section (figure to the right); the figure to the left is a side elevation. The young draughtsman should study the relation of the different parts and of the three views given to each other; this being facilitated by the working transferred from one to another by the dotted lines.

In fig. 1, Plate CXXXIV., we illustrate the method of finding eccentric lines to give the outline of a heart-shaped "cam." In this *d f* is the throw of the cam, and the circle *b c d e* the size of the curve. Draw the circle or eye of the cam *a f*. Divide the circle *b c d e* into any number of equal parts,—the greater the number, the more the number of points through which the curve is to be drawn,—and through these points draw radial lines to the centre *p*. Divide *f d* into a number of equal parts, amounting to half of those into which the circle *b c d e* is divided. Then, from centre *p*, with radii as *p g*, *p h*, *p i*, etc., describe circles concentric to *bcde*: the intersection of these with the radial lines as 1 *p*, 2 *p*, 3 *p*, etc., will give points through which the curve will be drawn. Thus the intersection of the first circle, *p g*, with the first radial line, *p* 1, will give the first point, *q*; of the second circle, *p h*, with the second radial line, *p* 2, will give second point, *r*; the point *s* is found at the intersection of *p i* with *p* 3, *t* at the intersection of *p j* with *p* 4, *u* at cutting of *p k* with *p* 5, the point *v* at cutting of *p l* with *p* 6, point *w* at cutting of *p m* with *p* 7, point *x* at cutting of *p n* with *p* 8, point *y* at cutting of *p o* with *p* 9.

In fig. 1, Plate CXCIV., we show how the heart-wheel cam described in preceding paragraph is lightened by having void spaces, as *a a*, *b b*, cast in the central web or plate in the same manner as done in the case of the eccentric in fig. 1, Plate CCXVII.; a rib or feather, *c c*, being used to strengthen it, and also to give a symmetrical division between the two sides. When the cam is designed to give motion to a rod, as *d*, which rises and falls alternately in the direction of the arrows *f* and *g*, the conical part, as at *i*, requires to be formed as at *h*, in order to facilitate the motion of the friction-wheel *e c*, which is placed at the lower extremity of the rod *d*. In some mechanical movements the heart-wheel cam as now illustrated works inside a rectangular frame, to the end or ends of which the rod or rods are jointed to which the reciprocating rectilineal motion is desired to be imparted.

THE TECHNICAL POINTS CONNECTED WITH THE EMPLOYMENT OF FORM AND COLOUR IN INDUSTRIAL DECORATION.

CHAPTER VIII.

All we have said at conclusion of last chapter may appear to some of our readers as having but little, if indeed anything, to do with the subject of art decoration. We have in truth written but in vain if this be so. Nevertheless we are bold enough to maintain the assurance that it will not appear thus to the majority, certainly not to the thoughtful amongst our readers. To them at least the truth of all we have said will be clearly perceived, nor less its application to the purposes of our paper. These purposes will have been but poorly served if we have in any measure lost sight of the fact that the mere execution of the art student is *not* all that is to be thought of,—if in any way however slight, or by any words however feeble, we have given our readers to suppose that all that is required in the art student is the capability to do what may be truly called the merely mechanical part of his work. Assuredly our purpose has, from all we have said, been vastly different from this. The facility of finger to commit to canvas, to wall surface or to paper, the forms and figures the eye sees, or fancies it sees, is right enough in its place: it cannot possibly be dispensed with. But while drawing is in itself indispensable, drawing is not all. Nay, at the best it is but, so to say, as the tools with which the workman shapes his materials into form. But what that form is depends upon higher attributes. Design comes in here, to give the stamp of value to his work; and, as elsewhere in the pages of this work it has been shown, design in its only one and true sense is dependent upon thought for its existence. Drawing and design as such are therefore quite different things, although in perfect work the two must go and be together. But of the two—although some, we know, will think differently—the work which is deficient in drawing, yet shows in every line the evidence of design, is of far higher value than that in which every line is drawn with that accurate precision which gains prizes and certificates, yet is but the evidence of a capability of copying and nothing more. Some of the work of the old masters in the decorative art of materials which we now call industrial—as glass, gold and silver, iron and wood—are, when judged by the mere mechanic's standard, wofully deficient. Some of our youngest apprentices could, to use a graphic if a familiar expression, "beat them hollow." But as works of true art—that is, as strong evidences of thought, of design—they stand so high that they are models for all time of what decorative art in such materials should be. We cannot therefore possibly have done wrong to insist—the wrong to our readers would have been had we refrained from insisting—upon the art student having the highest aims in his work, upon the absolute necessity which exists that he shall so study that those aims shall be secured, and so cultivate those sources of inspiration in art from which only those higher aims can be best attained.

Effect of Distance in Drawing Objects.

From what has been said as to the close study of Nature, in order to draw from her those lessons in art which she alone is capable of giving in such profusion of wealth and with such fulness and directness of purpose, it will be by the intelligent reader clearly enough perceived by this time, as he will have intelligently followed us, that this study depends much, if not wholly, upon his ability to observe—to see. It will also have been made clear that this faculty of observation, of seeing things in nature as they are, is very much a matter of education. To few only—and these are emphatically the "seers" in more ways than one—is the faculty given of going right to the heart, the centre, the soul of things visible in the created world around us. It is not given to every one to take in the varieties, or rather, as we should say, the true characteristics of form, to understand the mysteries and appreciate the delights of colour. But, as we have said, those things can be gained, though gained only by keen and close observation. And, as we have also said, one way to gain them—some maintain that it is the only way—is to begin with the study of the minuter objects in nature, going from them to grander developments in form, light and shade, and colour. But there are several points in the matter of seeing or observing natural objects which it is necessary the student should be careful in noting and giving earnest heed to. One of these is that the same object does not present the same artistic or natural characteristics—for our purposes we take these terms to be synonymous or convertible expressions—when viewed from "differing distances." The aspect which a rock or a tree assumes when viewed from one distance is quite different from that which it offers to the eye of the artist when observed from another distance. This is quite different, be it marked, from the effect of looking at the same object from different points of view; for it will be at once obvious that the mere form of the object may be, and very likely will be, seen from one point, quite different from that seen from another point of view. And as with the form, so with the light and shade and the tones or tints of colour. The mere change of position will give to the eye of the artist light-and-shade and colour effects which will be so strikingly different from what he had seen before, that the most

indifferent or apathetic may be startled into some activity of thought and clearness of observation or keenness of sight. But although this effect of change of position or point of view is one which the art student must take every available opportunity to study, and studying to understand, it is to be noted here that it is one quite different in its features and results from that which we have named above—that is, the change in the appearance of a natural object brought out by the mere change in the distance from which it is viewed. Thus, it is true that "for every distance from the eye there is a peculiar kind of beauty, or a different system of lines of form; the sight of that beauty is reserved for that distance, and for that alone. If you approach nearer, *that kind* of beauty is lost, and another succeeds, to be disorganised and reduced by strange and incomprehensible means and appliances in its turn."

The Artistic Effects of Natural Objects.

From this, and from what we have otherwise and elsewhere stated in this paper and that under the head of "The Ornamental Draughtsman," enough has been given to impart to the youthful student in art decoration some conception of what work is before him in his study of nature and of what are called the artistic effects of natural objects, when properly looked at or seen. A somewhat contradictory-looking phrase this is—"of artistic effects of natural objects"—seeing that we are generally taught in the schools that art and nature are two totally different things, if not quite, at least greatly, contradictory. And although the dictum is reiterated and enforced by many writers out of school, it nevertheless is the fact that *true* artistic feeling and expression—the reader will note the word we have italicised—is that only which is natural or derived, and more or less directly displayed from nature. Nor must the art student, in his study of the special subject for the purposes of which this paper has been written, for a moment conceive that the lessons which we have shown can be derived from nature in artistic work have little or nothing to do with the special application of artistic knowledge to the decoration of industrial materials or work. It is not so now, or at best but in a meagre, moderate way; but in times past it was that our first artists, our greatest painters, did not disdain to show their powers, not merely in the decoration of the wide expanses of grand walls and ceilings of palaces, but in the design of a casket or the decoration of a cabinet which might grace and beautify, and in so doing enrich in a high sense, the modest apartment of a burgomaster. And when a higher and more noble knowledge of what art is, and what its mission to the people is, obtains amongst artists, we shall have a return of such times as those we have alluded to. And when we think what those old and bygone days were considered from the artistic point of view, there is much need also for those interested, or said to be interested in art now, to push the inquiry, so that, if possible, some answer, if only but a partial one, be obtained to the question, How is it that art has not the same influence, does not occupy as wide a field, now as it did then? When we fairly settle in ourselves to solve this question, determined that we shall obtain the true reply to it, we greatly fear that the evidence which will be obtained from all sides will be as little flattering to our vanity as it will be complimentary to our earnestness of thought and our purity of purpose. Nevertheless we have so far advanced in integrity of artistic purpose, and in what we may call the honesty of artistic life, that we may fairly cherish the hope that we are about to enter, if indeed there are not signs enough around us that we have already entered, upon a new phase of artistic (natural) life, which will in its work affect, as it will in proportion to its earnestness dignify, the existence or daily life of all classes, not less the poor and humble than the rich if not the vain. Far from hopeless, then, is the outlook of the future; but the more likely is the hope to be realised if the individual artist determines that in his walk of life, however narrow, in his circle of influence however circumscribed, he will do his share of this work of the future wholly independent of what is done by others, not measuring his efforts by what he sees of those of others. The day of the realisation of any hope never comes when the work which can alone bring it about is put aside because we wait for the work of others. It is individual effort which forms collective and completed work.

In this work of the individual, in which alone rests the hope of the future of artistic work in industrial decoration, there are many points which come up for close consideration. To some of those, and perhaps the most important, we have drawn attention more or less complete. But one or two still remain to be glanced at. We have said much about colour and its application to artistic decoration—much also as to form, and what can be taught respecting them by nature; and much more could be said—for the subject, like the examples of it which abound in nature, are inexhaustible and varied as they are infinite. But one thing is to our mind very clear: that neither noble nor pure work—if, indeed, the two attributes of nobility and purity can be separated—will be secured without nobility of thought and purity of purpose. As the outlines of the face and the play of expression in its features may and often do—although in this, as in other things, facts belie experiences—give a trustworthy key or clue to the intellectual and moral character of a man, so it may

be said, as indeed it will not seldom be found, that the colour-work of a decorative artist gives the key to his character. For just as we know, beyond any doubt, that a man habitually given to the utterance, even in connection with the most trivial circumstances, of impure words, has a mind filled with impure thoughts, so also may we decide with almost equal certainty that certain combinations of colour or a certain style of colouring habitually employed by some artists—for example, in cold, gloomy greys or browns, or in dashes of what should be brighter colours, but which being impure in tone, are not bright, but lifeless—give us a fair key to the intellectual, and above all, moral character of the artists themselves. A pure mind animated by noble thoughts and aiming at the highest purposes will be certain to give pure effects. We have had to examine decorative work designed for wall surfaces the very colour of which told the tale of the mind of the artist—it being almost impossible to conclude otherwise than that he had an impure mind. And the effect on the minds of those who were condemned daily to look upon that decorated surface could not have been otherwise than depressing, even if it were not essentially degrading. Some may think—a few possibly (we hope but a very few) may go the length to say—that art has little or indeed nothing to do with moral considerations; that a thoroughly worthless and bad man may be a very good artist—may, indeed, be able to point to certain examples in proof of this. There can, however, be no greater mistake made by the young artist than this, and it will be well for him if he is not misled by the miserable sophistry of those who maintain it to be true. There is art *and* art—the true, the noble, and the false and monstrous. The tendency of true art is to elevate the mind and purify the affections; that of false art, even at its best, tends only to tickle the fancy, at its worst tends to lower the moral tone. It is an easy matter to find the truth of this exemplified in the works of the old masters; we do not mean by this term their paintings—popularly pictures—but their decorative work, although both classes of work may be cited as examples of the truth of the position we have put. Our great authority—for none can be greater than he in all that is connected with the morality of art, which we at least look upon as its life—has some fine and noble remarks upon this, maintaining that the "purest and most thoughtful minds are those who love colour the most," and that the "more faithful and earnest the religion of the painter, the more pure and prevalent is the system of his colour. . . . And it will be found that so surely as a painter is irreligious, thoughtless, or obscene in disposition, so surely is his colouring cold, gloomy, and valueless." As examples of the "opposite poles" of art in this respect he quotes the cases of Fra Angelico and Salvator Rosa. Of the work of the first-named, a man who "never harboured an impure thought," he says that his pictures are "simply so many pieces of jewellery, the colours of the draperies being perfectly pure." Of the work of the second artist named, "a man who spent his life in masquery and revelry," he says "his pictures are full of horror, and their colour for the most part gloomy grey": and our authority concludes by saying that "those are no singular instances. I know," he says, "of no law more severely without exception than this of the connection of pure colour with profound and noble thought." We have in another part of this paper referred to a certain "school" of Continental colourists whose work may also be taken as proof of this law. This work, almost without exception, if not degraded to a terribly low degree in subject, is always in colour of the most depressing character—depressing almost to repulsiveness—the examination of which gives one a mental shock much in the same way as one knows a pure-minded man is shocked at the outpour of the blasphemy and the obscenity of talk of some impure-minded and impure-living scoundrel. And of this school of colourists here alluded to it is in no wise uncharitable to say—for they make a boast of it, "glorying in their shame"—that the best of them lay no claim to purity of life, while of the worst of them their lives are best characterised in those terrible words—"they are given over to a reprobate mind." If any youthful student of ours may not think it true now, the time will, we think, soon arrive when he will find it abundantly evident, that the better the man, the higher his aims, the nobler his purposes, the purer his thoughts and aspirations, the better the artist and the more likely is he to do some of the good work, which, while it gratifies what is called pure artistic taste, does more and higher work in elevating the mind and bracing it up to the execution of good deeds which will live, to the cultivation of high thoughts which will fructify to noble lives. It will be a great day for British art when the decoration of even our humblest homes is deemed a matter worthy of the care and of at least some portion of the work of our best artists; a still greater day for our national art when its followers, one and all, rise to a true conception of their mission, and of those principles or that spirit which will dictate the execution of its work in such a way that, while it pleases the eye or gratifies the taste, it will also minister to the love, the cultivation and the enjoyment of the pure hopes and the noble purposes of a dignified and dignifying life. We say this, for we confess to being ambitious for the future of our national art: too often it has lent itself to the mere gratification of the gay and thoughtless, to the passing whims and fancies of fashion.

THE GRAZIER AND CATTLE BREEDER AND FEEDER.

THE TECHNICAL POINTS CONNECTED WITH THE VARIETIES OR BREEDS OF CATTLE—THEIR BREEDING, REARING, FEEDING, AND GENERAL MANAGEMENT FOR THE PRODUCTION OF BUTCHERS' MEAT AND OF DAIRY PRODUCE.

CHAPTER XXVIII.

Breeds of Fattening Animals (*continued*).

WE said at end of last chapter that while the Devon ox is small in bulk as compared with the Shorthorn or Hereford, the form is generally finely set out and proportioned, giving a compact frame. A good animal has prominent eyes with placid expression, the nose is small, the horns are of graceful curves, with an upward growth and with outturned ends. The head as a whole is small, being described by some as "deer-like" in characteristics. The chest is round and deep, bosom open, fore-arms small and fine and tapering below the knee, and quickly lost in the shoulder. The back is level, the ribs springing clear and level; the skin is loose, touch fine, and the hair soft and fleece-like, having, when the animal is in good condition, a tendency to curl. The colour is a bright red, white spots or plashes, or of any other colours, if not positively objected to, being disliked as some evidence of a lower standard of excellence in breed; while a white udder, for example, is looked upon by many as an insuperable bar to purity, although overlooked by some.

The Shorthorn, the Hereford, and the Devon may be looked upon as the representative English breeds of fattening cattle, as the Galloway polled (or hornless) and the West Highland may be taken as the representative breeds of Scotland. There are, however, other English breeds, as the Sussex, the long-horned or Craven, the Norfolk polled or red polls, and the Suffolk polled (both, as the terms denote, "hornless" breeds), and the Welsh breeds. Cross-breeds are common enough, and this may be said to be the characteristic of the Irish cattle, which are distinguished by a very wide diversity in general features. The favourite cross in England is with the shorthorn, which shows itself, as in the case of the Yorkshire and Gloucester cross-bed cattle, to be singularly well adapted for bestowing its good qualities upon less highly favoured breeds or classes.

As the English cattle are classed under one or other of the four divisions—the long-horn, the middle-horn, the short-horn, and the polled or hornless, so the Scotch are placed in two great divisions—the horned and the polled. Of the horned class, the West Highland ox is the finest example; many of our readers, no doubt, recollecting at least one splendid specimen of this on the whole wild-looking but picturesque and noble animal, with its shaggy coat and splendid head, set off with horns of formidable and dangerous-looking dimensions. The colour of the West Highland ox is usually black, though dun is sometimes met with. They are finely and symmetrically formed, largish in bulk, with the straight and level back, level and well set-on ribs and tail, which please the experienced grazier. They are, as may be supposed from their habitat, hardy in constitution, and yield a large proportion of meat to that of their bulk, while its high quality is known to every butcher. The West Highland ox is a quick and kindly fattener; the county of Argyle may be said to be the home of the finest of the breed. The other varieties are the Kyloes—which is, in fact, the original or aboriginal breed of Scotland, the home of the best breed being the island of Skye—and the North Highland cattle, which come chiefly from the Orkney Islands and the counties of Caithness and Sutherland. Of the polled breeds of Scotland the Galloway is the representative; it is, indeed, very frequently termed the polled Scot. The colour is generally black, or a dark and brindled brown; the cattle are larger than the West Highland; their form is good, back broad and level, ribs giving a roundness to barrel or body, as good as in the best of English breeds. They are hardy in disposition, and fatten readily. Of the polled Scottish breeds, the polled Angus is the great rival of the Galloway, although, singularly enough, some insist upon its being but a variety of the Galloway. The polled Aberdeen is another breed of this class.

The Daily Work of the Grazier.

Having in the preceding chapters gone as fully as the space placed at our disposal will admit of into all the important points connected with what may be called the general principles which concern the calling of the grazier considered as an art or science (although it may with all safety be said that it is both), we are now prepared to go as fully into the actual details of his daily work. In giving these, we shall take in succession the different classes of live stock of the farm, which are bred, reared, and fattened for the production of food—namely, what is popularly known as "butcher meat," and "dairy produce," as milk, butter, and cheese. Those classes are fattening cattle, or oxen, and dairy cows. We consider that space will be economised, and at the same time all the practical details will be given, in what may be called a natural sequence, if, in place of devoting special paragraphs to different details, we take the work of the grazier as done from day to day throughout the year, thus presenting what we have to say in the form of a monthly calendar. Technically the farmers' year begins in October, the preceding month of September being taken as that in which the last of the work of harvesting, or the realisation of all the labours of the preceding months, is completed. It matters little,

however, in what sequence we take the months of the grazier; so that the usual mode of reckoning may be adopted, which commences the year with January.

Special Hints on the Management of Fattening Cattle.

Before giving our remarks under the various months, the following special hints on the subject of fattening cattle management will, in addition to those given incidentally while treating on the general subject in preceding chapters, be found useful. To obtain the highest economical results from the lowest expenditure of food, certain points must be observed in the management of fattening cattle. In winter, feeding, good shelter, and a due amount of warmth are essential. "Heat is meat" is a saying as amply verified by the experience of good and sound practice as by the dictates of correct theory. Two animals fed on the same food, and of like weights, one of which is kept during the cold months of the year well sheltered and warm, the other exposed to cold winds and wet, will give very different results, and all in favour of the animal well sheltered. Cleanliness of the house in which the animals are kept, as well as cleanliness of the animals themselves, should also be attended to. The important part played by the skin and its vessels in the animal economy is very much overlooked in practice. A hide loaded with dust and covered with dirt will keep the animal in a condition much less favourably inclined towards sound health than where the body of the animal is kept clean and sweet by being daily rubbed down with straw, and, in addition, well currycombed at least thrice in the week. The kind and quality of the food must be attended to, and to secure the utmost degree of economy in the use of these, the feeding time should be kept up with the utmost regularity. Irregular feeding exercises prejudicial effect upon the fattening of the animals, inducing restlessness and uneasiness, which simply means loss of food, as does excitement of any kind. Hence the animals should be kept as quiet as possible, never over-driven or needlessly disturbed. It is therefore scarcely necessary to add that, apart from other considerations, "cruelty is costly." Kindly treatment of the animals is therefore to be aimed at if economical fattening is desired. The food should be prepared in clean vessels if cooked, and given to the animals in clean mangers. A goodly supply of pure fresh water should be secured; and it is right to say that it is a growing opinion amongst good feeders that it is better to give a constant supply of water in the troughs than to adopt the plan of giving them occasional supplies. Opinion is divided as to whether the food should be given to the cattle cooked or in its natural state, and whether roots should be given them whole or sliced or pulped. We are in favour of giving occasional feeds of cooked food, and decidedly in favour of pulping—at least, slicing the roots and cutting the straw—mixing the roots with feeding meal. In using any of the condimental meals now so largely employed, and of which there are several in the market, it should be well mixed with the pulped roots and chaff. If cooked food is given, these meals should be mixed with it after it is put into the manger, and just before it is given to the animal. As animals frequently show a dislike to all sudden and marked changes of food, such condimental foods should be given in small quantities at first, beginning to use it gradually, increasing the quantity till the full allowance be reached, which will vary according to the condition of the animal. A great deal of discussion has been given to the question whether condimental or seasoning foods should be given, but it is only right to say that the belief in their great utility is becoming universal. Many who were once strenuous opponents of are now believers in them; and certainly Nature herself teaches the lesson of their value, for "seasoning" plants abound in all our pastures and meadows.

The Grazier's Monthly Calendar of Work.

January.—As regards the management and care of young stock and store cattle, we have but little to add to the general remarks which will be found in the month of October,—remarks which, with their attendant counsels and cautions, are applicable to all the trying winter months of the year, and this month is certainly not one of those which will test least the care, the skill, and we may say the ceaseless patience of the stock feeder; for without the last attribute or gift we fear that he will show but a poor balance-sheet at the end of the agricultural year. To the usual and general style of feeding for store cattle—namely, roots and straw—it will not be a loss if a daily allowance of oil cake be added; and from the too often repeated meals of the one root—the turnip—a change occasionally to others, such as mangold-wurtzel, will be beneficial. It is to be regretted that the style of farming usually adopted with us in this country does not admit of a much wider variety of feeding stuffs grown on the farm than is met with. Although to meet the demands of winter feeding is always more difficult than that of summer, and this for obvious reasons, we still might, by a little study and attention, increase even the winter's store. Thus parsnips and artichokes (Jerusalem), although as a rule but little esteemed, deserve to be highly so, especially perhaps the former, although the Jerusalem artichoke is a most excellent feeding root. Parsnips are highly valuable, and they possess, for this climate of ours, the inestimable advantage of being able to stand almost any degree of frost, as indeed artichokes also. Both are liked by all stock, and both are good as giving a change which we have shown to be beneficial. A capital food as an addition

to their usual food, of rather a cold and not very appetising kind, which *young stock* receive, is cut straw (oat is the most nutritious), pulped roots, with a gruel of linseed meal and bean meal—the linseed corrects the binding properties of the bean meal, which is a highly nutritious food—poured over and well mixed with the mass. The store cattle will be all the better for the same food; but as some feeders will grudge them this who believe that this class of stock should never have aught else than cold raw turnips and hard wheat straw, many compromise the matter by giving it them occasionally, as children in old-fashioned times used to get amongst the labouring classes a cup of tea—so called—on Sunday evenings. In all cases salt should be added to all mixtures of food, and if this do not form part of the food, but dry straw and roots be given only, a lump of rock salt should be placed where the stock can get to lick it. Salt plays an important part in the animal economy, and this is shown by the eagerness with which they partake of it.

Fattening cattle should have their food increased in its nutritive nature the nearer they approach the period when they get ready for the shambles. The "dearest food is the cheapest" for this class of stock; dearness being of course supposed to include the best. Oil cake should form part of the daily food (from four to six pounds daily), and this may be supplemented by other cakes, as cotton-seed cake—really good artificial food—the oil cake being lessened proportionately in weight as these are added. The locust bean may also be given, as also the common field bean, in the shape of meal; the more frequent the changes, the better for the animal. As these and other foods are given, the roots will be proportionately reduced; and the colder the weather, the more frequently these are given in the sliced or pulped state, along with straw chaff, the better. The water must be of the best quality, and all the points already noted as regards housing must be attended to most assiduously.

February.—With young stock and store cattle, now as before, the great point to be attended to is to keep them in a constant state of progressive improvement, never allowing them to "go back"; as if this is allowed the stock keeper will find it an almost impossible thing to get them forward to the same point; for, as an eminent feeder has remarked, "All backening in young stock and store cattle is simply tantamount to permanent loss." All the points, then, as regards feeding, which we have elsewhere detailed, must be attended to with rigid care; and as regards shelter and due regard to warmth during the nights in severe weather, let the old proverb, "As the day lengthens the frost strengthens," be remembered.

What was said in preceding month will apply to this, so far as keeping the animals from exposure to cold, damp, and wet, and especially to sudden changes of temperature—most prolific causes of complaints and diseases, some of which baffle even the cleverest of "vets." Animals approaching the time when the butcher or salesman will be calling for them must be pushed on with the best and most nutritious food, to give the best effects, of which, in addition to the rules already in preceding month noted, pay special attention to the condition of the health of the animals —a remark, we may here add, peculiarly applicable to young stock and store cattle. Give a variety of foods, and this will give a zest to them which will make them to be all the more readily assimilated; and this will be increased if a handful of condimental food be added now and then, no matter how much may be said against such by scientific men. Not a few of our practical men know their value, and act accordingly. It does not follow that they need be bought; a clever feeder can make his own, and make it well, moreover. He ought to be independent of all extraneous sources as much as possible, and he may be to a greater extent than he wots of by thinking a little and experimenting.

March, with its blustering winds, which ought to but do not always blow, and its "pecks of dust," anxiously looked for by old-fashioned and not a few of the new-fashioned husbandmen, but not always got if ever measured, brings with it, or should, milder weather with its longer days, but it does not always do so. In its fitful changes, indeed, it may be taken as the representative month of spring, as October is that of autumn; and these try the patience and test the health of all varieties of live stock, so that special care has to be taken as to their health. As in October, so now, the occasional summer-like days tempt stock keepers to expose their animals somewhat too freely; and caught, as they often are, by the sudden return of winter, which loves so often and so dearly to "loiter in the lap of spring," serious damage is often the result. Hence no wise stock keeper will do what unwise ones so often do—turn out the young stock all night. This is truly taking time by the forelock all too speedily, and the result will be, as a rule, most prejudicial to them. A good deal of their time may be spent in the open air in the day time, so that they be not exposed to continuous rains and damp. If caught and kept out in wet, on their being brought into the house or sheds they should be well rubbed down with straw dry and clean. As regards their feeding and that of store cattle, the period of the year when farm produce in the shape of roots becomes scarce is approaching, and these should be economised as much as possible by the use of other feeding substances, such as named in other months. Now will be found the advantage of having a variety

of home farm produce; and to those we have named as helps to eke out the not always plentiful supply of turnips and mangolds, the only two roots which may be called the mainstay of the feeder—such as the parsnips and the Jerusalem artichokes—we may add the carrot, a root by no means grown to the extent it ought, considering its great feeding value and its keeping qualities. The potato also is esteemed by some feeders, although the most eminent feeder of the day by no means approves of the root for store cattle. For *fattening cattle* are weeded out, those ready for the butcher sold off, those becoming rapidly so pushed on with good food (see preceding months); while those which are drafted from the store cattle must be put upon more nutritious food than they are as a rule accustomed to get. The rule can never be too oft repeated as regards all young stock and store beasts: keep them *gradually improving*, never losing a single step of any advance which good feeding and careful management have given to them.

April, with its "showers and sunshine" alternating with proverbial regularity or rather proverbial fickleness, is now pushing on the young pasture grasses, so that many stock feeders are tempted to send their animals into the fields. This is anything but good policy, not merely from the fact that stock will do better to be kept up—those which are destined to be fed on pasture—for some little time longer yet, with, of course, occasional and more lengthened runs outside in special pasture or exercising fields near the steading; but because more harm will be done to the young and all too tender grasses by being trodden down and eaten up by stock at this early period of the year. Keep them out, then, for some time yet from pasture fields, till the grasses have made some considerable progress, and are well established. Greater loss is sustained by eating down early pastures than is generally thought of; the land, moreover, is so soft from the wet of the preceding months, that great harm is further done by the stock trampling the yielding soil and crushing down the tender herbage. If any fields have made great progress, it will be better and more economical every way to cut it and soil the stock with it in the houses or sheds. Young cattle and store stock should have their allowance of roots and straw mixed with some oleaginous soup, so to call it.

Fattening cattle should, in addition to turnips or such other roots as mangolds, have a supply of potatoes (for these as food see a remark last month), the roots being proportionately reduced in weight, say to seventy or eighty pounds, and potatoes thirty daily. To these should be added a quantity of oil cake, or a mixture of oil cake and meals of home-grown produce, or of foreign substances, such as locust beans, lentils, and Indian corn. The weight of these may vary from six to eight pounds daily; the nearer the period for the "knife," the greater the weight given. All these foods are best given mixed with chaff, and either prepared as a meal or moistened with boiling water. In place of oil cake rye cake may be used (for which see remark in a preceding month).

May.—This is the first month which may be said to bring with its genial weather considerable supplies —at least in the more early districts—of green foods, to supplement and eke out the fast failing supplies of those, as roots and straw, which have formed the winter feeding stuffs. Autumn and winter sown successional crops of rye and vetches will have come into use; and in the latter part of the month the pastures will afford a firm enough bite to enable some of the stock to be turned out. Great care will, however, be requisite to accustom the animals gradually to the changes of food, for those from one kind to another, as from dry to green and luscious foods, are apt, if suddenly made, to give rise to various complaints.

Young stock turned out to pasture when such are ready during the day should be brought home and housed at nights, and a feed of some nutritious food be given to them along with their usual feed of straw, chaff, and turnips, or other roots, before being housed for the night.

Store cattle are now usually turned out to grass for the season, but as "sharp frosts" are often experienced during this month, it will be the wiser policy to house them for the night till the weather is fairly settled. It is but poor policy to lose what has been gained during preceding months by attention given to them through inattention and neglect now.

Fattening cattle ready for market are despatched thereto, and the store cattle, which have been gradually brought forward up to a certain point of condition by the feeding recommended, are brought in to take their places in the yards, stalls, or boxes. With these, as with the other stock, if green food, as vetches, etc., are ready for them, due caution must be taken to accustom them gradually to the change of food. Many a good beast has been put greatly back, subjected to serious and indeed sometimes fatal attacks of disease, by lack of attention to this important point.

June.—This may be said to be the first month of the new season during which stock are put out to pasture, or fed or soiled with cut green food in yard, stall, or box. The labour of the stock keeper is thus greatly reduced. Still idleness or rest forms but little part of his work, if the paradoxical statement may be allowed, as there is plenty to do if doing is cared for. Young stock put out to pasture should be kept up in the houses or yards till the dew is dried off the grass, as it is very prejudicial to their health to eat grass dew wet.

THE CABINET MAKER.

THE TECHNICAL DETAILS, AND THE PRINCIPLES AFFECTING THE DESIGN OF HIS WORK.

CHAPTER VI.

Further Practical Points on the Designing of Furniture.—Thinking out of the Purpose it has to serve—or its Utility.

TAKE, again, the case of easy chairs. So called!—for many are so made that they are by no means easy to sit on, or rather in. We say "in," for the idea which dominates the design of an easy chair is that of an enclosing space, within which space one sits to be thoroughly comfortable, shielded at the back and sides from those draughts and cold currents which are so prevalent in even our best ventilated rooms, and in which one can lounge and be thoroughly at rest. The very same principle which dictates the position of the seat of an ordinary chair, and which we have endeavoured to explain above, applies to an easy chair, —only with just so much the greater force inasmuch as, while an ordinary chair is not always used for the purpose of obtaining rest, being often employed chiefly for convenience, as when sitting at table, an easy chair is really designed for rest and repose, and for nothing else. Its very size and weight preclude it from being moved about from place to place conveniently. It is therefore, as a rule, kept in one place—generally at some cosy corner of the room—near the fireplace, round which Englishmen love to cluster. With the easy chair, therefore, the idea of rest and repose is invariably associated; but it is not always so well designed that either one or the other can be obtained by its use. This arises from either a positive ignorance on the part of the designer, or from carelessness in applying his knowledge, if he possess it, of what are the true physiological facts which dictate what rest in one sitting or lounging is. Whether the cause of bad design be the one or the other of those named, ignorance or indifference, the practical result is the same—bad work. We have shown that all strain thrown upon the limbs is antagonistic to rest of the body. The seat, therefore, should be such as that strain is taken off the limbs; and this will be greatly effected by giving the seat a backward inclination. This should primarily be done by adjusting the relative length of the front and back legs, but it should also be secured by the method in which the chair is upholstered. Too many easy chairs—we might say nearly all—are so upholstered that the front part of the seat presents the aspect of a little hill with very steep side sloping to the front. So that if one sits down, feeling an inevitable tendency to slide down or off the seat, a strain is thrown upon his legs to prevent the catastrophe of a descent to the floor. A little thought on the part of the upholsterer would obviate this unpleasant position, and would give a seat so made that on sitting down there would be a sense of repose in the mere stability, so to say, of the part sat down, so that the position once taken, one would intuitively feel that it could be retained without any physical exertion. The sense of uncertainty, the feeling that one will sooner or later have to move in order to adjust oneself to the seat, are thoroughly antagonistic to perfect rest and repose. There can be no true repose where there is movement or a desire to move.

The exercise of a little thought would obviate, we have said, any such inconvenience; but the misfortune of the matter is that this thought, however little of it may be required, is not always, not often, given. Its exercise is neglected but too completely and too frequently in other points connected with easy-chair design. We have said that one characteristic of this piece of furniture is its having roomy space in which to lounge. But is this space always given with judgment? Enough is only required, but if too much be given the attribute of cosy shelter is lost in proportion to the excess. What, then, in practice do we too often find? A breadth of seat or width of space between the enclosing sides calculated apparently with the notion that two people are to sit upon it in place of one. This excessive width adds unnecessarily to the dimensions, and therefore to the weight, and of course to the costliness of the chair; and it is subversive of true comfort, which requires ample space only for easy movement of the body, but not wide vacuities which the body only of a giant would fill up.

The Value of Thought given to the Designs of the Cabinet Maker, further and practically Exemplified.

But if the width or breadth of easy chairs be excessive, what is to be said of the depth—that is, the length of the seat from front to back? We have seen that to get the repose which an easy or any other form of chair should give when one sits down for the purpose of obtaining rest, all strain should be taken off the legs, which is best done by giving the seat a backward tilt or slope. To gain repose, the back of the individual must also be supported. For to sit bolt upright in a chair, however otherwise well designed to give rest to the legs, would scarcely be looked upon as rest or repose by a wearied man. Back support is therefore necessary; and this, while upholstered so as to be soft and yielding, should be so adjusted in its backward angle or slope as to be in harmony with the angle or slope we have seen to be essential for rest on the seat of the chair. But no matter how well designed the position of, or how comfortably upholstered, the back of the easy chair may be, what if the back cannot be reached without bringing into operation certain strains upon the limbs which it is the very object of the designer of the easy chair to prevent? We say,

"if the back cannot be thus easily reached." That it is a difficulty so to reach it, and yet to keep the body easy, in many instances of easy chairs, requires but a little observation to see clearly. The depth from front to back is so excessive in many easy chairs, that when the support for the back, which we have seen to be so desirable, is wished for, and the sitter sits well back to get it, what is the result? In nine cases out of ten, taking the average height of men and the length of their legs, if the back of the sitter be leaning against the back of the chair, his legs are so drawn up that we have seen little men so sitting have them absolutely horizontal, their feet projecting outwards, and but a little way, moreover, from the front, so preposterously long was the seat of the chair from front to back. With men not absolutely little, but still not tall, their legs, though hanging down, still fall short of the floor; and even in the case of ordinarily tall men, such is the length of the seat that, when sitting fully back in it, their feet do not get a proper hold of the floor, so that a certain strain is thrown upon the limbs. To gain all the rest which such easy chairs with preposterously long or deep seats from front to back can afford, one would require to be a giant of seven to eight feet in height.

But while rest for the back and freedom from all strain upon the legs are requisite in a chair deserving of the name of "easy," rest also for the head is necessary. To a wearied man, worn out with work of brain or body, or to one desirous to take "forty winks" before or after dinner, it is a matter of no small disappointment to find, on throwing back his head, that it falls, not upon a comfortable and firm resting-place, but upon the vacuity of space. Or if, to avail himself of the back of the chair so as to find a resting-place for his head, he finds that this can only be got at the risk of losing his seat; for he has to throw himself so far forward that he is very nearly pushed off the seat altogether, and a strain is thus thrown upon his limbs. There must be but few of our readers who have attained mature years, very few indeed of those past middle life, who have not had experience of this kind. In an easy chair, thoroughly deserving of the name, and capable to give rest to the whole of a man's wearied frame, limbs, body and head, for which alone it is designed, provision is required for the rest of the head. The back should therefore be high, at least in the central part, to afford support for the head; and the designer should endeavour to arrange this part of the construction so that it will be a comfortable resting-place. What notion of the true office of this part of easy-chair construction can a designer have when he terminates the back of it with some bold projecting carved work, such as we have seen in easy chairs? Even a hard-headed man would object to resting the back of his head on such a knobby or knotty surface.

That the form of the back, or rather the outline of the upper part or edge of it, should be considered, is, we think, clear enough; but it is not always, we may say with truth seldom so. What is the condition necessary to be observed? Obviously, rest or repose for the head. How can that be secured if the wearied man who is trying to get "forty winks" is perpetually waking up at short intervals to bring up his head to the proper central point, which he wakes up to find sliding away down the steep and smooth sides of the convex curved outline or moulding at the back? It is obvious that if the central part of the chair back and top be rounded—that is, if the back moulding be formed of a part of a circle or a curved line, placed so as to give a convex surface, there can be no real resting place for the head. An effort will always be required to keep it at the highest part of the curve, where stability alone can be secured. Take, now, a back so formed that the central part will be a concave. This will naturally form a hollow part into which the head will fall; and if this concave part be proportioned to meet the average size of head, it will be so supported on either side as to give a real resting place to the head during the process of taking "forty winks."

In taking up the inquiry into the design and construction of chairs, which we have now concluded, we warned the reader not to expect a like criticism on the design of other parts of furniture. Nor do we deem this necessary; for at the same time we pointed out that our chief aim in entering upon the inquiry was to show the young technical worker in and designer of furniture to think out all the objects which each article was designed to serve, or which they should serve. This exercise of thought we deem to be of the utmost importance, for upon it rests absolutely the hope and the work of the future. For when thought is given by the bulk of the trade we shall find that all the anomalies and "practical absurdities and inutilities"—to quote the words of an authority on the subject—at present existing in the furniture of our houses will cease to exist, or at least be very greatly modified and largely done away with. It is, however, not only necessary to have a desire to think over all the details of one's calling; it is equally necessary so to think that the best results of thought will be obtainable. There are, be it remembered by the youthful technicalist, thinking *and* thinking: that is, thought well directed, logically used, and thought which is so ill directed and so objectless that it is practically little better than dreaming, or castle-building in the air. Thought, to be worth anything, must be patiently, and, as may be expressed, tautological as the term may be, thoughtfully thought out. In work like that we have been considering, the faculty of analysis—of "pulling a thing to pieces," "turning it inside out"—is most valuable.

THE GEOMETRICAL DRAUGHTSMAN.

His Work in the Construction of the Figures and Problems of Plane Geometry, Useful in Technical Work.

CHAPTER XIX.

Methods of Describing the Oval (*continued*).

Another method is shown in fig. 5, Plate CCXXXIII., in which let *a b* be the length of the egg; divide this into three equal parts in the points *c* and *d*; from point *c*, with *c a*, describe the circle *f a g d*. Bisect the distance *d b* in the point *e*, and from *e* as centre, with *e d*, describe the circle *d e b*. Through the centre *c* of the large circle, draw at right angles to *a b* the line *h i*. With the distance *a b*, from the points *f* and *g*, set off to the points *i* and *h*. From *h* and *i* as centres, with *h g*, *i f* as radii, describe arcs joining the small circle *b* with the points *f* and *g*.

Drawing the Curve of the Oval through Points found by Intersecting Lines.

Another method is shown in fig. 99, in which *a b* is the length of the egg. Through these points, at right

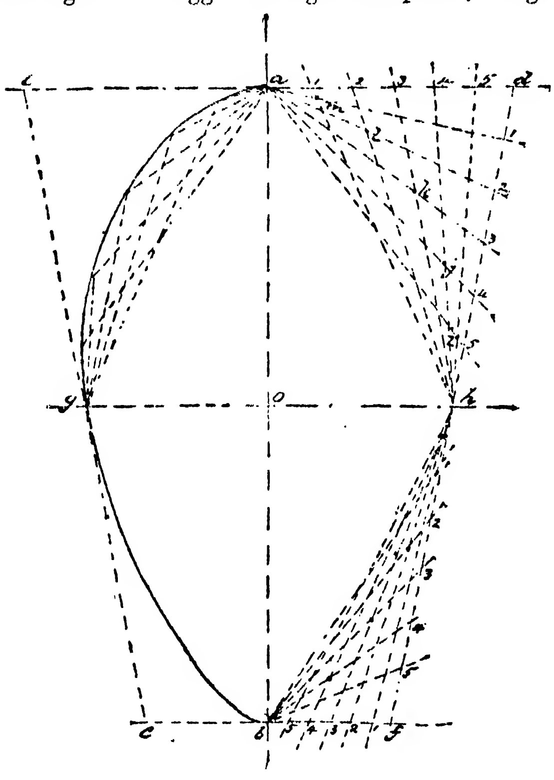


Fig. 99.

angles to *a b*, draw lines *c d*, *e f*, and make these of unequal lengths and in any proportion desired, and join *c e*, *d f*. Divide *c e d f* into two equal parts in the points *g* and *h*. Divide *b f*, *f h*, each into the same number of equal parts, and number them in the relation to one another as shown. From the points in *d h* draw lines to the point *a*; and from the points on *a d* draw lines to the point *h*. The intersections of these corresponding lines—as the line *a* 5 with the line *h* 5—will give points, as the points *i*, *j*, *k*, *l* and *m*, through which if a line be drawn by hand or "curve set," one-fourth of the egg will be drawn; the remaining three-fourths, as those between the points *b g*, *g h* and *c h* being put in by a repetition of the process already described, and as shown by the dotted lines in the diagram.

It will be observed that in the methods of describing what is called the "egg-shaped oval," as in figs. 4 and 5, Plate CCXXXIII., the upper parts, as *a d b*, *f a g*, are semicircles. In the true egg-shaped oval the two halves on the opposite sides of a line, as *a b*, fig. 100, are equal, and symmetrical. The following method will give the curves of this form. Let *a b*, fig. 100,

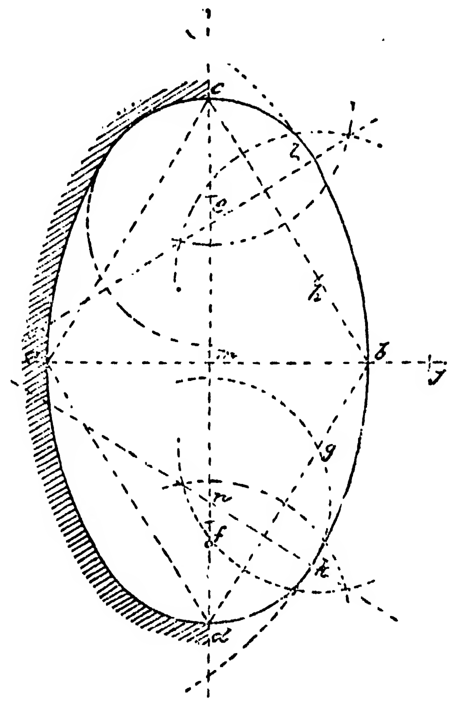


Fig. 100.

be the shorter diameter or breadth, and *c d* the larger diameter or length, of the desired egg-shaped oval. These diameters intersect as shown in point *m*. Join the points *b d*, *b c*. From point *m*, with radius *m b*, set off to point *e* and *f* the longest diameter, *c d*. Make *b g*, *b h*, in *b d*, *b c*, each equal to the distance *d f* or *e c*. Divide the distances *d g*, *h c*, into two equal parts by the bisecting lines *k* and *l*, cutting the diameter *a b* prolonged or extended in the point *i*. From *m*, with *m i*, set off to point *j*, equal to *m i*. From the point *i*, with radius *i b*, describe the arc *k b l*, terminating at points *k* and *l* on the lines *i e l*, *i k*. From the points *e* and *n*, as centres, with *n k* as radius, describe arcs *l c*, *k d*. This will complete half of the figure. The

other half will be described from centre *j* and centres *e*, *n*. The reader will perceive that this figure gives a very good approximative ellipse.

Curves other than the Ellipse.—The Parabola.

In the preceding chapter we concluded the problems connected with the ellipse, which we have seen to be one of the most important figures with which the geometrical draughtsman has to concern himself, connected as it is with such a wide variety of "projections" (see the "Building and Machine Draughtsman") in the practical work of mechanical construction of all classes. We now proceed to the consideration of the curves or curved lines known as the parabola and the hyperbola. The others, which we have in a preceding chapter named the cycloid, epicycloid, and involute, will follow.

We have seen that the sections of a cone by lines parallel to its base are circular; but that if the cutting line is oblique to its base, the section is that of an ellipse. The section of a cone by a line parallel to one of its sides gives a curved surface to which the

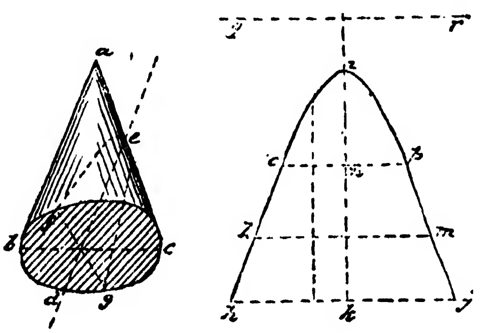


Fig. 101.

name of the parabola is given. This curve is very useful in practical technical work, as what are called "parabolic curves" are frequently used. Thus in fig. 101, if the cone *a b c* be cut by a line parallel to the side, as *d e*, the section is the parabola *e f g*. A line, as *i k*, passing through the centre of the curve is called its "axis"; the point *i* being the vertex, the greatest ordinate, as *h j*, which gives the length of the curve from the vertex *i*, is called the "base." All lines drawn at right angles to the axis *i k* within the curve are called "ordinates," as *l*, *m*. The ordinate, as *o p*, which passes through the focus *n*, is called the "parameter." The distance *i k*, or that limited by the vertex *i* and *k*, the line of greatest ordinate, or the base, is called the "abscissa," the line *q r* is called the "directrix." All the points of a parabolic curve are equidistant from the focus *n* and from the straight line or directrix *q r*, fig. 101.

We deduce from this definition a simple mode of describing the curve of the parabola. Fix a ruler or straight-edge, as D D′, fig. 102, along the line which should serve as the "directrix." Place against this ruler one of the sides of the "set-square" of 45°. At the extremity, C, of the other side of this "set-square," we attach a cord or strong thread, the length of which is equal to this side K C; the other end of this thread is fastened to the point F, which is taken

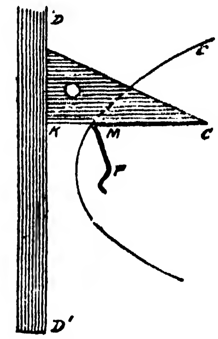


Fig. 102.

as the focus of the parabola. If, then, K C is slipped or moved along the ruler holding the thread stretched against the side K C by means of a pencil M, the point of the pencil will describe the curve required. In this method we have, in fact, constantly M K = M F, since from the dispositions taken K M + M C = M F + M C. It is, however, evident that we could not thus describe anything more than portions more or less extended of the parabola; these portions will be large in proportion as the sides of the set-square are long.

The following is a method of finding a series of points through which the curve of a parabola may be drawn by hand. From the point F, fig. 103, assumed as the focus, drop a perpendicular F D_0 on the directrix D D′. Through a point *m* of this line draw a parallel to the directrix, then from the focus F as centre, with the length *m* D_0 as radius, describe an arc of circle which cuts this parallel at a first point, M; this is one of the points in the curve of the parabola required. If we drop M K perpendicular to the di-

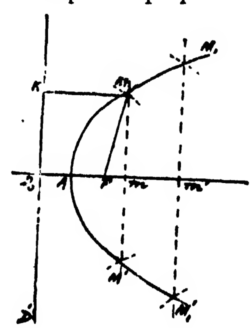


Fig. 103.

rectrix, we have M K = *m* D_0, and consequently M K = M F. The same arc of circle which we have just described furnishes a second point, M′, situated below the line F D_0, and at a distance M′ *m*, equal to M *m*. The line F D_0 is the axis of the curve, both sides being sym-

metrical to this. The point A is called, as we have seen, the "vertex" of the parabola; from the definition of this curve we should have $A\,D_0 = A\,F$. The vertex of the parabola is thus found to be situated at an equal distance from the directrix $D\,D'$ and the focus F. The distance $F\,D_0$ (fig. 103), from the focus of a parabola to its directrix, is called, as we have seen, the "parameter" of the parabola.

To find the Curve of a Parabola by means of Points.

The following constructions will be found useful in finding the curves of parabolas produced under varying circumstances. Let *a d*, fig. 1, Plate CCXLVIII., be half of the base, and *a b* the height of the parabolic curve required. Draw *b c* parallel to *a d*. Divide the distance *a d* into any number of equal parts. From what has been said in the papers entitled "The Building and Machine Draughtsman" on the drawing of curved lines, and to which the reader is here referred, he will see that the more numerous the dividing parts are, the more accurate will the curve be. Number the points as in the drawing, making No. 1 nearest the centre line *a b*; and from the points draw perpendiculars to the line *b c*. Divide now the height *c d* into the same number of equal parts as *a d* is divided into—as four in the drawing—and number them as shown, the 1 starting nearest the point *c*, so that the 4 on the line is nearest the 4 on the line *a d*. This relative number must be attended to, otherwise the result will be erroneous. From the points on *c d* draw to the vertex or apex of the curve *b* the lines as shown. The intersection of the line on *c d* with line 4 on *a d* will give a point *e*; lines 3 with *f*, and 4 with *g*. Through these points draw the curve as shown. The other half of curve may be found in the same way. Or the system of ordinates may be used. Thus, from points *e*, *f*, *g*, on the curve, draw lines parallel to *a d*, as *e*, *l*, *m*. Then from the points where these cut the centre line *a b*, as *h*, *j* and *l*, measure to points *g*, *f*, *e*, and set them off on ordinates, as *e*, *l*, *m*, to points *i*, *k*, *m*, and make *a n* equal to *a d*. Draw a curve through these points from *b*, terminating at *n*; it will be equal and similar to the curve *d e f g b*.

Another method is illustrated in fig. 2, Plate CCXLVIII., in which *a b* is the abscissa, *a c* the diameter, and *d c*, *a e*, a double ordinate. Through point *b* draw a line *f g* parallel to base or ordinate *d e*. Divide *a d* into any number of equal parts, as four in the drawing, and from these draw lines to the point *c*. Draw *f d*, *g e*, parallel to *a b*, and divide these into the same number of equal parts as *a d* is divided into; and from the points draw lines to the point *b*. Number the points in *f d*, *d a*, as shown, and the intersection of corresponding lines will give points as *h*, *i*, *j*, through which a curve to *b* is drawn; point *h* being connected with point *d* by a straight line which completes half of the parabola. The other half is put in as shown, or it may be found by means of ordinates, as in fig. 1, Plate CCXLVIII. In fig. 3, Plate CCXLVIII., we also illustrate the adaptation of the same method to the finding of a parabolic curve: the double ordinate *d a e* is in a "canted" or "oblique" line. The letters of reference are the same as in fig. 2, same Plate.

In fig. 4, Plate CCXLVIII., we illustrate another method of finding the curve of a parabola, in which the diameter as *a b* is given, and the axis *c d*. Continue *c d* indefinitely towards *e*, and make *d e* equal to *d c*. Join *a e*, *b e*. Divide *a e*, *b e* each into the same number of equal parts, as six in the diagram, taking care to number them in the order shown. Thus the point 1 begins at the foot of the right-hand line, as *b e*, and the point 1 on the line *a c* begins at the top. Join now the correspondingly numbered parts, as the point 5 on the line *a c* with the point 5 on the line *a b*, 4 with 4; the line from 3 goes right across from the line *a e* to the line *c b*, the point 2 on the line *a e* joins

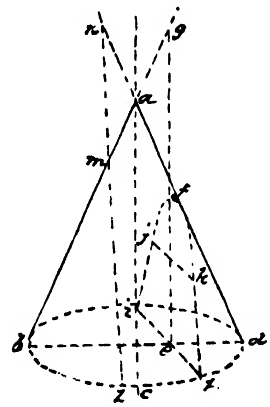


FIG. 104.

with the point 2 on the line *a b*, and 1 with 1. The intersections of these lines give points through which the curve is drawn. These joined by a curved line beginning at point *a*, going round by *d*, and terminating at *b*, will give the curve of the parabola required.

The Curve known as the Hyperbola.

The "hyperbola," like the parabola and the ellipse, is a section of the cone: while the ellipse is produced by a line cutting the cone oblique to its base, and the parabola by a line parallel to its side, the hyperbola is produced by a line, as *f e*, fig. 104, parallel to the axis, *a c*, of the cone *b a d*. Or it may be produced by any other line, as *l m*, provided always that if that line were produced it would cut the side of the cone opposite to it also produced. Thus the line *l m* cuts the side *d a* produced in the point *n*; and as the line *e f* produced cuts the side *b a* produced in the point *g*, the line cutting the cone, as *e f*, is called

the "axis" of the parabola, the line or base $i\ h$ the ordinate, $e\ f$ the abscissa, and that part, as $f\ g$, of the line from f to where it cuts the opposite side of the cone produced in the point g, is called the "transverse diameter"; all lines drawn within the curve at right angles to the axis are called ordinates. The "centre" of the hyperbola is a point midway of the transverse diameter, or the point midway between the points f and g.

The usual and most simple method of finding the curve of a hyperbola so closely resembles that adopted in the case of the parabola that the curves may practically be said to be identical. In fig. 1, Plate CXLVIII., there is shown a method of finding a hyperbolic curve, the ordinate $a\ c$, the axis $a\ b$, and abscissa or height of the curve $a\ b$ being given. Through b draw $b\ d$ parallel to $a\ c$ and $d\ c$ parallel to $b\ a$. Divide $a\ c$ into any number of equal parts, as five in the diagram, numbering them from point a, beginning with 1. Divide also $d\ c$ into a similar number of equal parts, numbering the points so that the point 4 will be nearest the point 4 in the ordinate $a\ c$. Through the points on $a\ c$ draw lines parallel to $b\ a$, and from point b lines through the points on $d\ c$. The intersection of the correspondingly numbered lines will give points, as e, f, g, h, through which, if a curved line be drawn, it will give the half of the curve. The other half can be put in in the same way. But the simplest method is to carry over from the points, as e, f, g and h, ordinates cutting the central line, $a\ b$, in points i, k, m, o. From point i, with distance $i\ h$, set off to point j on line $e\ j$; from point k set off $k\ l$, equal to $k\ g$; from point m set off $m\ n$, equal to $m\ f$; from point o set off $o\ p$, equal to $o\ e$; and make $a\ q$ equal to $a\ c$. Points are thus obtained through which the curve will be drawn.

The Curve known as the Cycloid.—Method of Describing it.

The cycloid is a curve generated by a point in the circumference of a circle which rolls along a straight line. The head of a nail, for example, projecting from the tire of a carriage wheel which is rolling along a level road describes a curve in space which is the cycloid. The curve commences at a point in the level line where the diameter of which the point is the lower extremity is at right angles to the line as the line of road along which the wheel is rolling, and the curve is concluded when the point assumes the same position in relation to the road or level line, after the circle or wheel has completed the revolution; the length of which distance, $b\ d$, fig. 1, Plate CXLVIII., is equal to the circumference of the circle. This relation of the length of the plane or level line to the circumference of the circle gives a method of describing the curve as follows:—

Let $a\ b$, fig. 1, Plate CLXXVII., be the diameter of the rolling circle. From the point b draw at right angles to $a\ b$ a line, $b\ d$, and make it equal to the circumference of the circle $a\ b\ c$. If the line $b\ d$ is made equal to eleven of the seven parts into which the diameter $a\ b$ is divided, this will approximate nearly to the circumference of $a\ b\ c$. Next divide the distance $b\ d$ into any number of equal parts—say eight, as in the drawing. From these parts, as e, f, g, h, etc., draw at right angles to $b\ d$ lines, as $d\ l$, $e\ m$, cutting a line $c\ m\ l$, drawn parallel to $b\ d$ through the centre c of the circle $c\ b\ a$. Next divide the semi-circumference, $n\ b\ o$, of the rolling circle, $a\ b\ c$, into the same number of equal parts as the distance $b\ d$ is divided into, as in the points p, q, r, s, t, u and v. Next, from the points on the line $c\ l$, as l, m, etc., describe circles of the several diameters, equal to $a\ b\ c$. Next take in the compasses the distance $n\ p$, and from the point e on the line $b\ d$ cut with this distance the circle, the centre of which is at m on the line $c\ l$; the point of cutting is at w. Then, with the distance $n\ q$, from the point f cut the circle described from the centre d in the point x. Next take the distance $n\ r$, and with it from the point g (on the line $b\ d$), cut in the point y the circle described from the centre c' (on the line $c\ l$). Next, with the distance $n\ s$, from the point h (on the line $b\ d$) cut in the point z the circle described from the centre f' (on the line $c\ l$). Next, with the distance $n\ t$, cut in the point a' the circle described from the centre g' (on the line $c\ l$). Next, with the distance $n\ u$, cut in the point b' the circle described from the centre h' (on the line $c\ l$). Finally, with the distance $n\ v$, cut in the point c' the circle described from the centre i'; on the line $c\ l$ a series of points, as $d, w, x, y, z, a'\ b'\ c'$, will thus be obtained. through which by hand or a "set curve" the cycloidal curve may be drawn. This will give half of the curve due to the revolution of the rolling circle, $a\ b\ c$, The whole curve will be terminated at a point to the left of the point b, equal to distance $b\ d$, and the various points of the curve will be found by a repetition of the operations on the right-hand side of the line $a\ b$, named above.

Another Method of describing the Cycloid Curve.

Another method of finding a series of points through which a cycloidal curve may be drawn by hand is illustrated in fig. 2, Plate CXLVIII., in which $a\ b\ c$ is the rolling circle and $b\ d$ the line on which the circle rolls. At right angles to $b\ d$ draw the diameter $b\ c\ a$. Divide the semi-circumference into any number of equal parts, as eleven, as in the drawing in the points $f, g, h, i, j, k, l, m, n$ and o. Then from b, on the line $b\ d$, set off the same number of equal parts as at the points $p, q, r, s, t, u, v, w, x$ and y. Next, from these draw at right angles to $b\ d$ lines, as $p\ z$, $q\ a'$, $r\ b'$, $s\ c'$, etc., cutting the line $c\ j$, drawn through c parallel to $b\ d$.

THE SANITARY ARCHITECT.

THE PRINCIPLES AND PRACTICE OF HIS WORK, IN HEALTHY HOUSE ARRANGEMENT AND CONSTRUCTION.—TECHNICAL POINTS OF SEWERAGE AND DRAINAGE, VENTILATION, ETC.

CHAPTER XI.

IN following up the subject of the practical points connected with the materials used in the construction of drains, begun in the last paragraph of preceding chapter, we have, in connection with the drain tubes made in various forms and dimensions of earthenware glazed or vitrified, stated that they have largely, practically wholly, superseded the old forms of brick built drains. As compared with these, the new tubes offer this enormous gain in efficiency: that they are water-tight, so that what is passing through any part of a tube cannot pass out from it through its exterior surface, and penetrating the soil surrounding it, percolate or soak through its particles, thus making it, in process of time, a mass of soil either partially saturated with sewage so as to be damp, or so nearly saturated as to be semi-liquid and in a condition very little better than the sewage itself, which it is the office of the drains to convey away from the house as fast as possible. This state of matters, as regards the filthy condition of the soil surrounding a drain, was in many cases the normal or regular state of brick built drains of the old times, used universally, and to a large extent used still. This arose from the structural defects of this form of drain, by which in the first place there was a great difficulty, almost an impossibility, to get a form by which the quick conveyance of the sewage away from the house was secured, so that the sewage often lay in what might be called an elongated stagnant pool in the inside of the defectively formed drains. In the second place, their structural defects made it an almost equal impossibility to have the drain made water-tight, so many joints being of necessity existent even in a comparatively short length of drain. These two grave defects in brick built drains gave rise to the condition of soil surrounding them above noticed; and when we consider the fact that they were of necessity made for part of their length immediately in contact with the house, a system became established which it is impossible to conceive of being worse. They were, indeed, often carried through or across the house, being led immediately under the floors, not merely of the passages or lobbies, which was bad enough, but under those of the living rooms, which was infinitely worse. We may form some notion of the sanitary evils which arose from this cause alone.

So great were those evils that the most earnest attention of our medical men and those connected with the health of the population was directed to the subject, with a view to overcome and remedy them. The difficulty, however, was not so easily met at the first stages of the agitation, if so this new sanitary movement may be termed, inasmuch as no means offered themselves, or were apparently likely to offer themselves, by which the mechanical or structural difficulties of brick or stone built drains could be overcome, and that was where the main difficulty lay. Nor was it lessened by the fact, then as now unfortunately existing, that through the carelessness of the workman who constructed the brick drains the inherent evils connected with them were multiplied and intensified. Fortunately, however, coincident with a very early stage in the history of the sanitary movement, a discovery or application of old materials to a new purpose, and worked out by a new, ingenious, and thoroughly effective method, was brought before the world, which solved the difficulty. Need we say that this was the use of clay moulded into the form of the tubes we have just referred to, and then vitrified or hard-burnt in a peculiarly arranged furnace or kiln, and which gave to our architects, builders, and sanitary engineers the modern "drain-tube"

So remarkable were the results of the use of this, and so satisfactory in a sanitary sense were they that the idea became almost universally, or at least popularly prevalent, that the new drain-tube system of sewage possessed no faults. We shall see presently whether this was or is true or not, or whether it is not even now, when we should suppose that the advance made in the arts would have secured almost absolute perfection in their use, that we have much yet to learn in the matter of the use of the modern drain-tube. The truth indeed is, that, even when made in the best form or shape, made of the best material, and laid in the most careful fashion, the tubular system of drainage has its own peculiar defects, which are to be met or provided for in certain special ways. What those are, has already been hinted at in a general way, but will presently be specially described.

We have said that, from the condition of the empirical or rule-of-thumb practice of former days, house drainage, considered as a complete system, has taken the higher position of an art, details of which are based on the strict and accurate deductions of science. So far as the dealing with the liquid portions of house sewage or the refuse of domestic and trade operations is concerned, the department of physical science upon which its practice is based is that of hydraulics, that of pneumatics being called in to decide all points connected with the treatment of the gaseous emanations arising from the sewage. Both are, indeed, more or less intimately intermingled, so to say, and the principles of both have to be considered before perfection in practice can be secured. The various scientific points involved in the whole subject

possess such practical value, not merely in direct relation to its practice, but to that of other important technical work, such as forms the subject of separate papers in this work under the head of the "Land Drainer," that space will be here usefully devoted to a somewhat detailed account of them.

The points connected with the department of house drainage now under consideration—namely, the materials of which the drains are constructed, the shape or configuration which is given to them, and the size or dimensions best adapted to do the work required of them under special circumstances—are so closely concerned with each other that it will be most convenient to consider them as forming but one subject. Thus the size or dimensions of a drain are dependent very much upon its form or shape, and this is dependent again to a large extent upon the material of which it is constructed, while in the third place the calculated results of size and shape or form are greatly influenced by the circumstances of the laying down and the construction of the drains.

Materials of which Drains are made—Brick Construction.

So far as the materials of drains are concerned, we have pointed out that in the modern or closed system of house drainage two classes or three are used—brick or stone and the earthenware tubes. To these a third, namely wood or timber, must be added here, inasmuch as in colonial districts that material is now and will for long be largely employed in drain construction. And as our work will largely and directly circulate in the United States as well as in our own colonial possessions, and will be read by many at present in this country but who may hereafter emigrate, it is necessary here to take note of this material for house drain construction, all the more that our notice of its application may convey definite information on some important points applicable to a wider variety of work. As regards the use of brick as a material for drain construction, special notice must be taken of it, inasmuch as it is still largely used even in this country, and as a material in advance of timber or wood largely in the United States and in some of our colonies. And in pointing out the character of the defective work so often done in this material, we may be able to give some hints as to how more correct construction may be obtained with its use. It would at first sight appear that brick possessed the attributes of soundness and durability. But this must be taken with the reservation included in the phrase 'There are bricks *and* bricks.' Good and sound bricks there are which will be durable enough in drain construction; but there are bricks made which possess the chief attribute in the estimation of some—namely, cheapness—but which being cheap are worthless just in proportion as the point of excessive cheapness so much desired by some is approached. It ought to be a maxim with all builders that cheap bricks should never be used in drainage work, which of all work connected with a house ought, in view of its health importance, to be of the soundest and the best. Some bricks are so poor in quality that they crumble away or break off in pieces even in the setting; and if not so bad as this are quite bad enough to decay, so to say, with great rapidity under the conditions in which they are placed in drainage work. If bricks, therefore, be used for the making of drains, as they will in many places still be used, especially in rural districts and in many parts of the United States and the Colonies, it will be specially necessary to use bricks of a sound quality, good hard burnt, clear ringing bricks when struck with the trowel. While the strength of a brick individually depends upon the way in which it is made, and a sound brick is an important factor in the getting of a drain calculated to resist the pressure to which it is subjected, this strength is of course mainly obtained by the form which the drain assumes when the bricks are in place. Some might suppose that drains of any kind would not be subjected to any great pressure when placed in the ground—at least to that which would crush them in and destroy their form. In many situations this will no doubt be the case; but in others, where there is traffic of carts or the like, there is danger of the continuity of the drain being destroyed by its giving way in some part under the heavy pressure of a cart, even though that be not often taken over the surface beneath which it is placed. Even in some private houses there are drains laid under roads over which heavy carts are occasionally passed. And a drain which may escape at one time from this danger may not at another, from some peculiarity in the condition of the soil. We have known brick drains—and the remark applies to tubular drains as well—broken up at more than one place in consequence of heavy carts passing over them, and only occasionally. In many cases heavy brick drains (and even the smallest-sized are pretty heavy per yard-run) are placed or bedded in soil so yielding and treacherous, some parts more than others, that unequal settlement is sure to take place; and if this be not the cause of the drain being wholly broken up in form, it is almost certain that in course of time the continuity of the drain will be destroyed, as illustrated in fig. 1, Plate CLV., this showing in an exaggerated form the effects of unequal settlement of the soil at points below *a* and *b*, causing open joints as at *a* and *c*. Exaggerated as the effects of this cause of injury to brick drains are shown in the illustration, cases as bad or nearly so are to be met with in practice. Even where the soil is so solid that little fear of a great depression or sinking of it may be entertained, still

an undue strain or pressure may be thrown more upon one part than another by a careless mode of preparing the bed or foundation of the drain, leaving hollow parts in it, as at *d* and *e* in fig. 1, Plate CLV. In this case the bricks bridging over these spaces depend wholly upon the goodness of the mortar; and when this gives way as it will sooner or later, according to circumstances and the condition of the sewage matter passing through the drain, the bricks will give way and separate at the joints, thus destroying the integrity of the drain as a continuous duct. One would suppose that defects in the foundations so glaringly bad as we have here illustrated would not be met with in practice; but as there is scarcely a way in which construction should not have been done but what is met with in the practice of drainage, it is scarcely necessary to say that defects of the kind we have noted are, at least have not been, uncommon.

Construction of Drains.—Form or Section.

These, and similar defects in the foundation of drains, are common to all forms, and however good the drains may be in brick construction, will seriously affect their strength to resist pressure. The mere form or shape has, however, the greatest influence in this regard; and it is worthy of note that the very worst forms which could have been fixed upon were those used in the great majority of instances during the period of house drainage history or practice when brick was the only material—save stone, and occasionally timber—used. The remark applies even yet to a large percentage of brick drainage practice, although it is perhaps more true of American and Colonial than it is of British practice. There was this to be said in extenuation of the practice, so common, of using the worst forms of drains—namely, that they could be much more quickly and easily constructed than those more correct forms which a knowledge of construction dictated. Thus, it is obvious that the form shown in diagram A, fig. 1, Plate CCXXXVIII., could be more quickly constructed than the corresponding diagram in fig. 2, same Plate; the one would require a higher degree of skill than the other, and would, in consequence, be grudged where cheap was thought more desirable to be obtained than good work. But it was long before the art of drainage had so advanced that good forms, such as in fig. 1, were met with in its practice. The bad ones, such as in diagram A, fig. 1, reigned almost supreme; this form here illustrated may be said to be the primary or elementary form in which the house drain appeared. In design it is but one step in advance of the simple rut or open channel adopted by the earliest of house drainers. The square form, where any body is subjected to pressure, is the weakest which can be given to it. The reader will thus perceive that the form cf brick drain shown in diagram A, fig. 1, is the weakest which could be adopted, liable to changes in its configuration by unequal pressures. Any defect in the bed or foundation such as we have already pointed out, acting, for example, as at *a b c* in diagram B, fig. 1, Plate CCXXXVIII., will obviously throw out the lines of the sides, as shown by the dotted lines. As the square form is the weakest, so is the circular the strongest, in which a hollow body can be made. Any approach to the circular in the shape of a brick drain will, in proportion, give to it a capability to resist external pressure put upon it, the evil results of which pressure will always be aggravated—in many cases, indeed, will be brought into play—by any defects in the foundation or bedding of the drains such as we have described in connection with fig. 1, Plate CLV. Thus, the form illustrated in diagram C, fig. 1, Plate CCXXXVIII., will be stronger than the form in diagram A; but, strong as this form is as compared with A, it possesses its weak points, and its integrity is apt to be injured by defects in the foundation r bed in which the base bricks, *d e*, rest, the straight parts, as *f f*, of the sides being the essentially weak part of the drain. By reversing the position of the curved part of the drain, placing it at the lowest point, as in diagram A, fig. 1, Plate CCXLIV., we get a weaker form than in diagram C, fig. 1, Plate CCXXXVIII. We shall presently see the effect of form or shape either in retarding or facilitating the flow of the liquid sewage along and through the drain; and how, while the form in diagram A, fig. 1, Plate CCXLIV., considered as a construction, is not so good as that in diagram C, fig. 1, Plate CCXXXVIII., it is the better form of the two so far as its hydraulic principle is concerned. It is only when we carry out the principle of the curved form for a hollow body completely that we get the strongest form in which a brick drain can be made: this is illustrated in diagram A, fig. 2, Plate CCXXXVIII.; and in another form, as in diagram C in the same figure, the curved principle of formation is also adopted. The relative hydraulic values of those two forms will be explained presently.

Brick Construction of Drains.

In our statement of the points of the "standard of perfection" in drain construction, we named as one of them that a drain should be impervious to water—in other words, when finished it ought to be waterproof, and should be so constructed that it will remain so. The necessity for this constructional prevision will be obvious from what we have said as to the nature of house sewage, and how imperative it is, from a health point of view, that it be not allowed to gain access to the soil, soaking into it and rendering it merely a deposit or resting-place for matter which will send up to the surface dangerous gaseous products. Now, if the bricks be good in quality, each *per se* is impervious, but from the very nature of brick con-

struction, so many individual or separate parts are required to complete a given length, that a very great number of joints must of necessity be made. And unless each joint be made what workmen technically call "good," it is obvious that the defective joint, wherever existing, will be an outlet for the liquid sewage to escape by. A brick drain, to be perfect in this respect, therefore, must have the best possible workmanship given to its construction; and not only this, but the very best materials must be used. How great are the chances that this is not done, those who know what an extent of defective and in many cases utterly bad work is given will easily understand. This defective and bad work arises, not merely from the carelessness which many workmen display at all times, but also from the desire of all parties concerned to have cheap work done. Not only, therefore, must the foundation be good and the bricks evenly laid, but the mortar used must be of the very best quality. In too many cases the desire to save expense prompts builders to use mortar of such wretched quality that it has scarcely cohesion enough to keep the bricks together even when lying in the circumstances most favourable to their retention of place or position, but it utterly fails to keep the bond of the bricks when these are subjected to any undue pressure arising either from defects in the foundation, as in fig. 1, Plate CLV., or in form, as in diagram A in fig. 1, Plate CCXXXVIII., and fig. 1, Plate CCXLIV. And the evils arising from the use of poor mortar do not end here. As used to make the joints "good," it is little better than a pure mockery; it has the appearance only of giving a good joint, for it may be said literally to melt or be wasted out, leaving the joints, more or less in proportion as this is done, open, this affording, even in a short length of drain, a great number of outlets for the sewage. So far as the form of brick drain illustrated in diagram A, fig. 1, Plate CCXXXVIII., is concerned, with all its faults it does possess this constructional advantage, that the bricks being placed parallel to one another, they lie close together over the extent of their faces or "beds," so that the joints are more easily made good with the mortar. But the case is different whenever the curved principle is applied to the form. According to this form, the bricks more or less wholly lie in diverging lines; and being in themselves parallel-faced, the joints are no longer parallel, as shown by the dark part in diagram E, fig. 1, Plate CCXXXVIII., but become angular, as in diagram F. How such forms of the joints facilitate the creation of the evils arising from joints acting as channels for the passage of the sewage from the interior of the drain when good mortar is not used, may be illustrated in the diagrams D in fig. 1, Plate CCXXXVIII., B in fig. 1, Plate CCXLIV., and B and D in fig. 2, Plate CCXXXVIII., which give parts of the curved surfaces. And all these defects are aggravated when the foundations or bedding of the bricks are not good, as in diagrams A and B, fig. 1, Plate CLV., and fig. 1, Plate CCXXXVIII.; or when the earth or soil is not well and carefully rammed all round the curved parts of drains formed as in diagrams A and C, fig. 2, Plate CCXXXVIII.

When brick is used for the construction of drains the reader will perceive that the best materials, the best workmanship in the adaptation and use, and the best foundation must be given, if good drains are wished for. It may, indeed, be taken as an axiom, that bad work is the dearest; for the drains which it gives are worse than useless for the end in view, since they are a dangerous delusion, giving the idea that drainage has been carried out, while they bring about a condition of matters in reality as unhealthy—some authorities say more so—than if there were no drainage at all. In this last case one negative advantage would, at least, be obtained: one would know what, or rather what not, to expect. But when work is supposed to be done which is not done, one naturally trusts to the arrangement as being efficient while in reality it is the reverse. If the proverb be true that a man forewarned is forearmed, it is not the less true that it is better for a man to know absolutely that he has not got a thing than to be deluded into all the danger of believing that he has it—and is therefore safe—when he has not got it. When the foundation soil is treacherous and uncertain, if good hard ramming of it will not give a firm bed, the only safe way is to lay the bricks upon a bed of concrete, as shown by the dotted parts in diagrams A and B, fig. 1, Plate CLV. In the case of the square drain in A, it will be rendered all the more liquid-tight if the concrete be brought a little up the sides, as to the points *a* and *b*, sufficient to secure a water-tight bed for the lower part of the drain. The same will be secured for the joints of the lower part of the circular drain in diagram B by bringing up the concrete on each side, as at *c d*.

Another point in the standard of perfection of drainage work which we have named is this,—that the drain shall throughout its surface be smooth, entirely free from all projecting parts. The effect of all projections in retarding the flow of the liquid along the interior of the drain is very decided. This is so even in the case of pure or comparatively pure water; but the evil arising from obstructions is intensified in the case of house sewage. This is invariably largely provided with solid and semi-solid substances, and grease or fatty particles form a considerable percentage of these.

THE COTTAGE AND THE VILLA GARDENER.

The Leading Principles and Practice of the Art of Family Gardening.

CHAPTER V.

Vegetable Marrow (*continued*).

In concluding our remarks under the head of the last paragraph in preceding chapter, we have to remark that one of the most successful growers of this capital table vegetable—for which a ready sale could be secured by the cottage gardener—adopted this plan. The shelter afforded by the ridges, and also by the leaves of the potatoes, which get pretty well developed by the time the "marrow" plants are pricked out, serve to favour the growth and development of the marrow, which under this style of cultivation seemed to us always to "fruit" better than when grown in the usual way on a hotbed.

Importance of the Scarlet Runner as a Food Crop for the Cottager.

It is worthy of notice here, and suggestive of some practical thoughts, that as a rule, throughout Scotland scarlet runners take no place in garden cropping. So unknown are the pods as articles of food, that an amateur flower gardener, and one of the most successful the writer has known as a mere amateur, and a man of education withal, on being asked by him why he did not grow them for food, replied that he never could think of such a thing, as they were, if not absolutely poisonous, very unhealthy. He was quite surprised to hear our statement of the utility of the crop—its beauty, and above all the delicious dishes the pods afforded. There is nothing, indeed, which surprises an English amateur—or, as we may call him, a family gardener—more in connection with family gardens in Scotland, than the very limited list of crops cultivated, as compared with those forming part of every well-stocked garden in the south. Some even of those most esteemed by the English family gardener are indeed quite "conspicuous by their absence"—to wit, the scarlet runner which has prompted these remarks; herbs, or savoury plants, may also be cited, as affording an illustration in point.

Taking this crop of scarlet runners as a very important one for the cottage gardener—who, if he has any to spare, can always as a rule find a market for them—it may, however, be said that, failing this market, his family could not use the large produce obtained from this method of easy and cheap cultivation of them which we have recommended. But should this be the case so far as the green pods are concerned, another use can be had for the beans. Allowed to ripen, seed will not only be secured for the next season, but the overplus will form a capital stock for winter dishes of boiled beans. The "white" variety of the crop, to which the name of scarlet runners cannot well be applied—except on the principle of *ucus a non lucendo,* scarlet because they are not so—give the well known white beans which are so often had in France, and called by the French haricot beans. Cooked in the way we generally cook these beans—and the scarlet variety, affording variegated and coloured beans, may also be classed as "haricot"—we do not wonder at their not being a favourite dish with us. But cooked as the French cook them, well boiled till they are quite soft, and served up with a piquant white sauce, they make a very toothsome dish. While on this point of cooking, we may observe that as a rule in this country the green pods, even, are not done justice to. Our cooks satisfy themselves by cutting the pods into two or three, or perhaps four pieces. Now, the full flavour of the pod can only be obtained—and this remark applies equally to the pods of the "kidney or dwarf kidney bean"—by cutting it into very small pieces, so small that they may be said to be minced. As to which of these methods is the best, let the reader try before deciding. If he has any taste at all, we have no hesitation as to which of the methods of preparing the pods he will prefer.

Let us glance at another plant—the "Indian cress." This is generally grown merely as a flower, and some of the varieties are very beautiful, even gorgeous in colour; but capital pickles can be made of the seed pods, while a leaf or two cut up small is thought by many to be a piquant and pleasant addition to a salad.

Soil of the Garden.

Having in the preceding paragraphs opened up the general subject, and drawn attention to several points connected with the cottage garden by which the most can be made of it, not only as a source of food supply for the cottage family, but, where larger space is possessed than is always met with, a source of profit may be obtained, we now proceed to take up the various departments of the practice of gardening, applicable alike to the cultivation of the crops raised in villa and cottage gardens.

The first points we have to consider are naturally those connected with the site and the soil of the garden to be cultivated. In the case of gardens attached to villas, the general rule may be said to be that the site of the garden is determined solely by that of the house. Only in rare cases have we known that the garden was considered to be such a matter of importance that the object of the proprietor was to gain a site as well suited for it as possible; feeling satisfied that if this was obtained, a good site for the villa itself would be sure to follow as a necessary consequence. We shall presently see that this theory is about as accurate as almost any other which could be held. Certainly the exact converse is far from correct: namely, that a good—or what is

supposed to be a good—site for the villa will necessarily be a good one for the garden attached to it. This, no doubt, seems to be the theory acted upon—assuredly in nine cases out of ten—in which villas are built on speculation in suburban districts. In this class of villas—and it is the largest and most extensive, the villas built specially for and by those who have the means and the opportunity to build for themselves, and according to their tastes and wishes, being few in number, compared with those built on the chance of finding tenants—the site for the garden is determined simply by what land is left over after the site for the house is selected, and such an extent of ground in addition to this which is to be given to such ornamental grounds as lawn and shrubbery.

In the great majority of such cases, as we have said, it is a very rare thing indeed to find that the builder has given special attention to the garden, so that the site for it would be as suitable for its purposes as the site for the villa would meet the tastes and wishes of the tenant. Indeed, so far even as the site for the villa is concerned, that is decided in a large number of cases, not by considerations of what makes really the best site, but by those connected with the fact that land—at one time farm or suburban ground—is so to be laid out and let for building purposes. The main point considered, or apparently considered, is whether the land so laid out is in what is called a "desirable neighbourhood," this phrase being considered to be equivalent to or synonymous with a genteel neighbourhood; the which, if attained, is deemed all that is necessary, if not by those who inhabit the villas, assuredly by the vast majority of the builders who cater for them. The claims of gentility being once met, other considerations, such as beauty and even healthiness of site, are too frequently put aside as matters of no moment. We know of one district, and that an extensive one, which by some means or other got to be considered a "desirable" or "genteel" neighbourhood, and which in consequence got thickly studded over with villas, some of them—indeed, many—being of a very costly character. And yet no architect, on the one hand, would have recommended the neighbourhood for house sites, as there was scarcely a plot in the whole district which afforded even a few of the elements of a good site, as regards attractiveness or beauty; while, on the other hand, a physiologist or physician would just as readily have decided that the whole district, and specially certain plots upon it, was by no means to be classed as a healthy or salubrious one.

Site of the House in Relation to the Garden.

Remarks on points constituting a good site for the villa or house as such will be found in the papers entitled "The Domestic House or Home Planner" and "The Sanitary Architect. And in considering those points, and what is now to be said, the reader will come to the conclusion that the view we have stated—that a good house site will give on the whole a good garden site—is about the most accurate which can be held. No doubt the grounds attached to a villa—this of course of the first class—may be so very extensive that, although the part chosen for the site of the villa may be in all respects good, other parts of the grounds may be bad enough if one or other of them be chosen for the site of the garden. And yet we venture to say, in such cases—and they have before now existed—that the chances are quite as much in favour of the bad site being chosen as the good one. And this arises not merely from the desire of the proprietor, but also that of his architect, that the garden and all its structures should be either so dwarfed in point of dimensions, or altogether so completely concealed from view, that it should not form a part of the estate or grounds to be seen by the public. The house or villa mansion in such cases is the one, the only, thing which is to have prominence, the one thing to which the public gaze is to be invited and public criticism challenged. The reader will of course understand that the term "garden" here used refers to the kitchen or useful garden, not to the flower-plot and shrubbery part immediately surrounding the house.

We have no hesitation in saying that this system of making the garden play quite a secondary part in the grounds of a villa is altogether a mistake. It proceeds upon a wholly erroneous assumption, and is in itself direct and decided evidence that there is an utter lack of true taste on the part of those who will tolerate its principle being adopted in its entirety, or even allow of its influencing in any marked degree the relative arrangement or connection of the house and its garden. Those who know best what constitutes the beautiful in nature and in art know best how great is the power of a garden and its accessories in adding to the attractiveness and indeed raising the dignity of the house. And so decided is this, that while on the one hand we should decide that the architect was ignorant of one of the powers of his art if he failed in making the garden accessories—conservatories, or the like—add greatly to the beauty of the villa and its grounds, so, on the other, we should decide that the gardener or landscape gardener failed in his conception of what power lay in his art to dignify and adorn the mansion, if he could not make even the "commonest of common" kitchen gardens a powerful aid in this direction, and cause it to be in itself a thing of beauty just as much in its own special direction as that of the flower and the fruit garden.

THE FARMER AS A TECHNICAL WORKMAN.

HIS TOOLS, IMPLEMENTS, MACHINES AND MATERIALS. —THE PRINCIPLES OF HIS WORK IN ITS VARIOUS DEPARTMENTS.

CHAPTER XIII.

Classification of Farm Crops.

In the last paragraph of preceding chapter we opened up this important department of our subject. Keeping for the present the grasses out of consideration, which form a very important series of green crops, the distinction between the grain or corn crops and the green crops may be broadly stated thus: that the grain crops are narrow-leaved, and the green crops are broad-leaved. Leafage, then, is the distinguishing characteristic of these two great or leading families of farm crops; and it is most abundant in the green crops, such as the turnip and the cabbage, the cereals or grain crops being distinguished by the small amount of leafage they possess. Now, it is one of the characteristics of plant growth that they derive from the atmosphere a certain and in one sense no small proportion of their constituents. The atmosphere, or air, to use the popular term, is therefore a source of supply of fertilising agencies, as much, though acting in a different way, as the soil or the manure given to it; and as the plants draw their supplies from this by means of their leaves, which are, so to say, their lungs, made up of an infinite series of breathing pores or spiracles, those plants which have the greatest amount of leafage or the greatest extent of breathing surface, so to put it, will derive the largest supply of atmospheric fertilisers. Hence is derived the practice, in rotation, of alternating the broad-leaved plants or green crops, such as the turnip or mangold, with the narrow-leaved grain crops, such as wheat, oats, barley, or beans. And as these crops alternate with each other in the system of rotation, that also is known as the system of "alternate husbandry." To this system, which owes its introduction in Norfolk to the celebrated agriculturist, Coke, of Littleton, may be attributed the immense improvement in British husbandry which dated from the latter end of the last century; for this system almost compels, so to say, the land to be cultivated in the best manner, as some of the crops which take part in the rotation can only give their best produce under the most careful treatment of the soil.

Rotation of Crops.—Four-Course System.

A fair general idea of the crops alternating in the rotation system may be obtained in a notice of what is called the "four-course" system, each year of the rotation being technically called a "course," each course extending over the agricultural year. Thus, the "four-course" system takes four years to work it round, so to say, to the starting point; the "five-course" five years, the "six-" and "seven-course" respectively six and seven years. Some rotations, as those markedly in the growing of what have been called the industrial crops, such as that of flax, extend over a much greater number of years than that last named, rotations of twelve or fourteen years not being unknown to the practical farmer. The oldest—that is, the first established rotation—namely, that by Coke of Littleton, already referred to, and often called the "Norfolk" course or system, from the name of the county in which it was introduced and in which it is still largely followed, is the four-course, in which the first year's crop on any given farm or field may be a grain crop, such as wheat, or (as in Scotland, where this grain is much grown) oats, the second year the land is devoted to clover, the third year to turnips, and the fourth year to barley. We have thus the alternation of broad- and narrow-leaved plants already noticed. But another and a very important end in the practice of farming is gained by this four-course system. Not only is the alternation of differently leaved or foliaged plants secured, but the condition of the soil required by one crop is secured in greater or less measure by the preparation required to be given to it for the crop immediately succeeding. Thus the clover precedes the wheat, and the peculiar characteristic of clover culture gives the peculiar condition of soil required for the wheat crop, which loves, as we shall hereafter see, a firm or consolidated seed-bed, but porous withal. Again, the wheat or oats precedes the turnips, the preparation of the soil for the grain crop suiting the necessities of the turnip crop; and this again precedes the barley, preparing the soil for it, which in time gives way to clover, and this again to wheat or oats.

Secondary Uses of the Rotation of Crops.

This secondary use of the rotation system is by no means unimportant in a practical point of view; indeed, not its least value is that the soil, in being prepared with reference to one crop only, is put or kept in the best condition mechanically suitable for the crops of the rotation considered as a whole. But there is another feature of the system of rotation which remains to be noticed. Not only is there an alternation of grain with green crops, but there should in a well ordered rotation be an alternation of the members of each special class or family. Thus the class of grains or cereal crops should not be represented by one grain only—say, for example, always wheat or always oats—but the cereals should alternate thus: if wheat is the grain crop with which the rotation commences, the next crop should not be wheat again, but barley, and oats should be taken next before the wheat crop again forms part of the rotation; three grain crops alternating, of course, with the green

crops, thus carrying on a double rotation or alternation. This, to be perfect, embraces also the green crops, in which the same system of alternation is to be observed. Thus, if the grain crop—wheat, barley, or oats, as the case may be—is followed by a green crop such as turnips, the next time that a grain crop is taken off and followed by a green crop, that should not be turnips, but another root, as mangold wurtzel; and as the green crop again comes round, the change should be again made, and this time potatoes may be substituted for the mangold wurtzel.

But this alternation of the members of the grain and green crops, considered as the two great classes, cannot always be carried out, the character of the soil compelling modifications of the rotation. Thus, some soils are pre-eminently wheat soils, just as some are barley soils; so that in the grain alternation of crops barley could not be perfectly alternated with wheat, nor would oats be admissible. In some modifications, therefore, of the "four-course" system, the seed crop beans, often classed as a grain crop, is taken after wheat, coming third in the course, turnips beginning it.

Rotation of Crops.—Forage.—Green Crops.

We have said that in the rough generalising of the farm crops there are only two classes—the grain and the green crops: there is, however, a very important series of crops known often as "forage" crops, of which the various grasses are the chief; and those play an important part in the rotation of general soils. Grasses considered as forage crops are classed specially, and as differing from grass properly so called, which takes the form of pasture and meadow land. The latter two forms in which a grass crop is met with are termed "permanent" or "natural grass"; the other grasses known as forage crops come under the class of "artificial grasses," forming part of the rotation system, alternating with the other crops, grain and green crops, which also form part of it. The various points connected with the cultivation of the different kinds of grasses, whether permanent or artificial, will be found described in a succeeding chapter, should space permit; meanwhile we name, as representative of the artificial grasses, that kind so well known as Italian rye grass. There are other forage—often known otherwise as "fodder crops"—of which rape and lucerne may be taken as representatives; while the clovers form a division or class of forage or fodder crops by themselves. We have seen that the clover forms part of the four-course system described in a preceding paragraph; this may be modified by introducing the artificial grasses. Those are generally, we might say universally, sown down with the barley crop—growing up to maturity after the barley crop has been taken off the land. Thus, a five-course system may be made out of the four-course by taking on the first year of the course, barley; second year, artificial grass sown down with the barley; third year, the grass cropped or cut for the second year; fourth year, wheat; the last year of the course being turnips, which is followed by barley, which again commences it. If the artificial grasses are cropped for the third year, the above five is changed into a six-course system; or this may be made by the following succession of crops, as (1) oats, (2) potatoes or mangolds, manured with farmyard dung, (3) wheat, (4) turnips, (5) barley, sown down with grass seeds, the 6th year being grass. A "seven" or "eight" course may be made by cropping the grasses twice or thrice in place of once.

Rotation of Crops.—Fallow or Bare Cropping.

We have classed the soils generally as composed of three great divisions—the heavy, the medium, and the light; each division being again subdivided into a number of soils, either approaching to or receding from the standard or highest point of each. In the heavy soils there is a class which yields a soil of such a tenacious and obdurate clay, so difficult to be brought into a condition fitted to bear crops, that a special system of working has to be adopted, which takes a regular place in the rotations or "course" system. This is termed the "fallow" year in the course, or "summer fallow." Fallow working may be here only generally described as a system of repeated workings of the soil, as by ploughing, cross ploughing, grubbing, clod crushing, and harrowing. Some of these operations are repeated again and again, the great object being to get the soil mellowed and bring it as near as possible to that well pulverised condition known as "tilth." And this not merely by the repeated mechanical action of the different implements used, but by what are even more powerfully acting mellowing influences—namely, those of the atmosphere, as light, air and moisture. Another important aim in the working of fallows is the getting rid of the weeds. These are specially prolific in lands obliged to be placed under fallow; as the soils are rich in fertilising constituents, forming as they do, in fact, the richest of of our lands, known often, indeed, as wheat and bean lands, both of which take out from the soil heavily its fertilising mineral constituents. The working of a summer fallow terminates in the autumn, when the land is finally prepared for the wheat crop, which usually takes the position of the first active crop of the course, although it is the second part or year, the fallow taking the place of the first year of the course. The wheat is usually followed by beans or pease—those being followed by clover, the barley closing the course—in which again a fallow comes round. This course is modified by taking beans after the wheat and clover after the barley. This resting of the land from cropping, or fallow, is

tantamount to the loss of a year's produce of one kind or another; and although it cannot be said to be a lost year literally, as by its work it insures, and in the only way possible under the circumstances, a condition of soil absolutely essential for the succeeding crops, still the great object of the farmer of such heavy lands, as regards the fallow system, is to bring the land into a condition to be cropped one way or another year after year, thus doing away altogether with the resting year. And it is not the least gratifying circumstance connected with modern farming, that by the introduction of new and carefully carried-out systems of soil preparation and crop culture, aided by improved mechanical appliances, and specially by the use of steam power applied to the working of those, fallow lands are becoming rarer and rarer; and many lands which could only be worked under the fallow system have become what it is the object of all heavy clay land farmers to make them—namely, good turnip lands—this term meaning soils capable of growing all kinds of root crops, as indeed it includes the widest possible variety of farm crops. We have said that to the introduction of the rotation system of which the pivot crop, so to call it, was turnips as a root crop, we owe all the improved methods of crop culture by which modern agriculture is distinguished. Before dismissing the subject of fallow land, it will be well to notice a distinction often made in connection with it. A fallow proper is sometimes called a "naked fallow," or a "bare fallow," to distinguish it, as in this case it bears no crop, from fallow land, in which part only of the whole land is treated as a naked fallow or fallow proper, or that which is put under a certain crop. This crop is generally turnips or mangolds, as those roots admit of the soil between the rows of plants being stirred, weeded, in other words, cultivated, during a large part of the growth of the plants—specially in the first stages of this. And from this circumstance such crops in such a treatment of fallow land are often termed "fallow crops."

Varieties or Systems of Rotation of Crops.

We have thus gone somewhat fully into the general subject of rotation of the crops, or of alternative husbandry; and it will form a fitting and practical conclusion to our remarks if we give special rotations as adapted for the leading varieties of soil — those given comprising systems adopted in different localities.

In very tenacious clay soils the following is adopted:—

(1) *First year,* summer fallow; *second year,* vetches fed off by sheep turned on to the land; *third year,* oats sown down with clover seeds; *fourth year,* clover. Of this clover crop the first growth is cut down to make clover hay, the second crop or aftermath is then fed off by sheep turned on to the land. The *fifth year* is wheat; *sixth year,* vetches fed off by sheep; *seventh year,* wheat. In this seven-course system the fallow comes every seventh year. (2) In other districts, with the same class of soil, the fallow comes every fifth year. *First year,* fallow; *second year,* barley; *third year,* beans; *fourth year,* wheat. In this case, part of the fallow land or course is only partially treated as a fallow proper—which, as we have seen, is called sometimes a naked fallow. One half of the land termed in this rotation and considered to be fallow land is cropped with some forage green crop, such as winter rye, or more usually vetches or tares, or a mixture of rye and tares, which makes a capital food for live stock in spring. This green forage crop is either eaten off by sheep, or mown, as in the case of the rye and tares, to be consumed by the live stock in the yards or houses. After the crop is thus taken off, the land is put under tillage or fallow treatment—that is, ploughed, cross ploughed, scarified, rolled, and harrowed—thus getting the land into as good a "tilth" and as free from weeds as possible, to be ready for the autumn crop. In the rotation still under notice a part of the remaining half of the fallow land is put under turnips or mangolds, these being well cleared from weeds, and the soil stirred as long as the work of tillage can be carried on. These roots are then fed off by sheep in the later summer, and the cleared land prepared for the crop. The remainder of the fallow land is left as a naked or pure fallow, and this part is purposely selected as being that part of the fallow which, from the nature of its soil, is required to be treated as a fallow proper. For, as we have already remarked, soils even in the same farm vary so much that one part of the land under fallow may be much worse—that is, more tenacious and obdurate—than another, so requiring a different treatment. (3) Another fallow rotation is: *first year,* bare or naked fallow; *second year,* oats; *third year,* artificial grasses sown down with the oats in preceding year; *fourth year,* wheat. (4) In another case the fallow rotation extends over six years: *first year,* fallow bare or naked; *second year,* barley or oats; *third year,* clover; *fourth year,* wheat; *fifth year,* beans; *sixth year,* wheat; the fallow again continuing the rotation, thus coming round once in every six years. As in all other systems of crop culture, the fallow system is modified according to circumstances, or ought to be, and with good farmers is so,—unless, as is but too frequently the case, the farmer is tied down by the rigid conditions of a lease which forbid him to crop his farm except in a certain way, and which under penalties he has closely to follow. On this system of rigid cropping by the terms of the lease, it is sufficient here to say that while at one period of the history of farming such restrictions might be necessary, guided

as they were by the then known practice and principles of farming, they are altogether beyond the necessities of modern farming, in which the principles upon which it is based are so well known, and are, in a sense more or less correct, so precise and definite, that the practice is now essentially different from what it was in days gone by. The farmer, then, ought to be able, under the conditions of his lease, to work his land in the way best calculated to meet its various and often varying circumstances, and to apply to its cropping and general management all the latest improvements which an advanced and ever advancing practice, no less than an eminently progressive science, are perpetually bringing forward to his notice. The value of a system of free cultivation will not be inaptly, in this place, illustrated by the statement that land which at one time was absolutely required to be worked as a naked fallow, is now, by continued and careful treatment, brought into such condition that it is capable of being put under crops, thus forming part of a regular system of rotation in which each year is producing something. In other districts, land which could not be cropped without being put under a naked or bare fallow can now, by improved mechanical means of cultivation, be rapidly brought into a condition fit to bear crops. Many lands which were thus, not so long ago, looked upon and actually treated as those capable only of being cropped by being put under fallow, are now good or moderately good turnip soils. In such cases it would obviously be to the grievous loss of the farmer if he were, by the rigid conditions of a lease—which were themselves the outcome of an antiquated practice exceedingly limited in its outlines—compelled to crop his land under the old system. We now come to notice rotations accepted for other classes of soils.

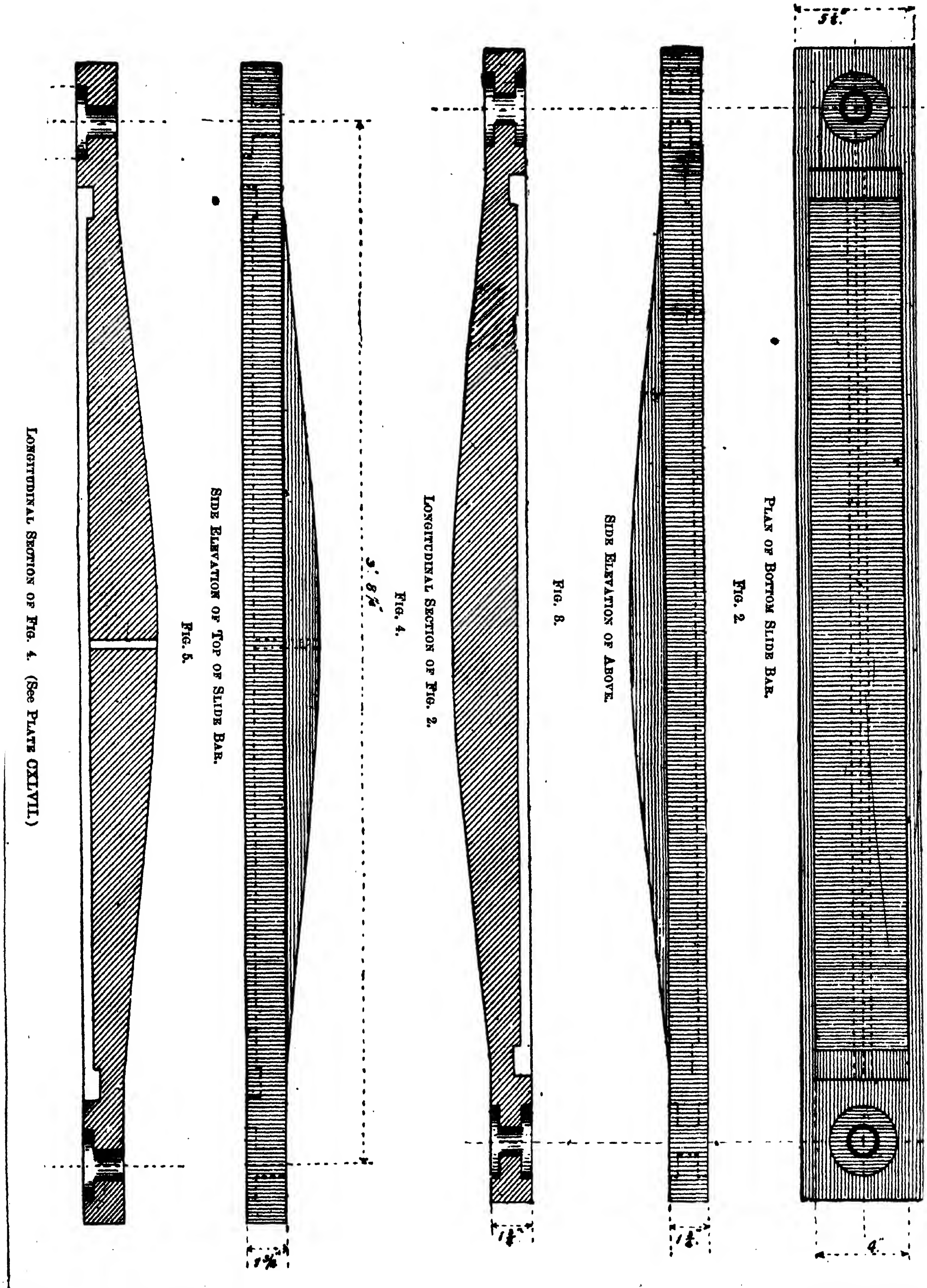
Varieties of Rotation (*continued*).

We take first "loamy soils approaching stiff or tenacious clayey or strong soils." For such stiff loams the following is a rotation which has been found to work well in practice:—(1) *First year*, wheat; *second year*, vetches (these are fed off by sheep or cut down for feeding stock in the farmyard or the house, and the land immediately prepared for a crop of turnips, such as the white or other quickly maturing variety, these being either fed off by sheep or pulled for yard or house consumption); *third year*, turnips or mangolds; *fourth year*, beans; *fifth year*, barley sown down with seeds, which give for the *sixth year* grasses (artificial). (2) Another rotation for stiffish or heavy loams is: *first year*, vetches; *second year*, wheat; *third year*, beans; *fourth year*, wheat. (3) A third rotation for strong soils, not well calculated for feeding off with sheep, is as follows: *first year*, turnips or mangolds; *second year*, oats; *third year*, clover (or half the land may be devoted to this crop, half to beans or pease); *fourth year*, wheat; *fifth year*, barley. (4) On stiffish clayey loams approaching to a black moor land soil, such as are to be met with in Lancashire, the following is a good rotation:—*first year*, oats; *second year*, oats (the crop of which is usually better than the first crop of this grain); *third year*, a root crop, such as turnips, mangolds, or potatoes (the last being a frequent crop in the above-named county); *fourth year*, barley sown down with seeds; *fifth year*, grasses which may either be fed off or cut down for hay.

For rich loams easily worked the following are rotations:—(1) *First year*, oats; *second year*, turnips or mangolds; *third year*, barley sown down with seeds; *fourth year*, grasses for one year (or making the rotation extend over five years, for two years), oats again commencing the rotation. (2) *First year*, turnips; *second year*, barley, either sown down with seeds, making the *third year* grasses, or beans or pease may succeed the barley; *fourth year*, wheat; *fifth year*, beans; and where the soil is stronger the rotation may extend to six years, the *sixth* being wheat, giving place to the turnips, which again commences the rotation.

On what are generally and favourably known as "turnip lands" *par excellence*, in which class of soils almost every farm crop can be cultivated, (1) the following is a seven-years rotation. *First year*, turnips, manured; *second year*, barley sown down with seeds; *third year*, grasses, those being mown for hay or for yard and house feeding; *fourth year*, grasses, but this time fed off as pasture; *fifth year*, oats; *sixth year*, roots, as mangolds, manured; *seventh year*, wheat. (2) A four-course system applicable to turnip lands, but not so good as the last named, is as follows: *first year*, turnips (the land is with this crop manured heavily to last for the whole rotation); *second year*, barley; *third year*, clover; *fourth year*, wheat.

The following are rotations suitable for varieties of soils other than those already given, such as (*a*) light sandy soils; (*b*) gravelly; (*c*) stone brash; (*d*) marls; (*e*) lias clays. (*a*) "Light sandy soils." (1) *First year*, roots; *second year*, spring wheat sown down with grass seeds; *third* and *fourth years*, grasses; *fifth year*, wheat. (2) Another rotation is: *first year*, forage crops, such as rye, rape, lucerne; *second year*, turnips, mangolds, or potatoes; *third year*, spring wheat; *fourth year*, pease; *fifth year*, wheat. (*b*) "Gravelly soils." (1) *First year*, turnips or mangolds worked as a fallow crop; *second year*, barley, followed by *third year*, clover; *fourth year*, wheat. Should the land become what is called "clover sick," winter beans alternate with the clover or pease; and of the clovers red and white alternate.



PLAN OF BOTTOM SLIDE BAR.
FIG. 2.
SIDE ELEVATION OF ABOVE.
FIG. 3.
LONGITUDINAL SECTION OF FIG. 2.
FIG. 4.
SIDE ELEVATION OF TOP OF SLIDE BAR.
FIG. 5.
LONGITUDINAL SECTION OF FIG. 4. (SEE PLATE CXLVII.)
3' 8½"
4"

THE ORNAMENTAL WORKER IN WOOD.—*ELEMENTS OF CUT-WOOD WORK.*

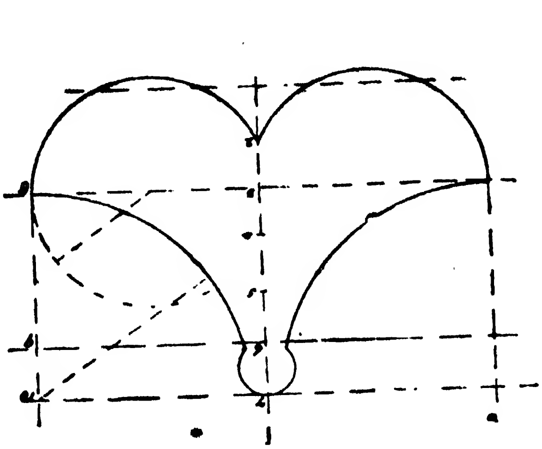


Fig. 1.

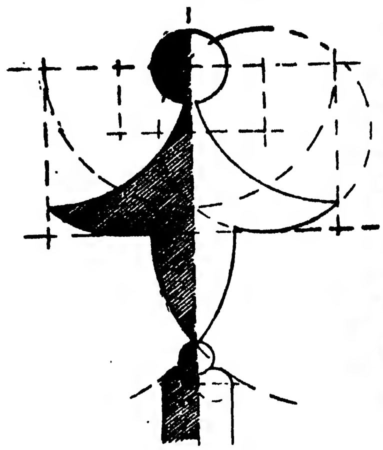


Fig. 2.

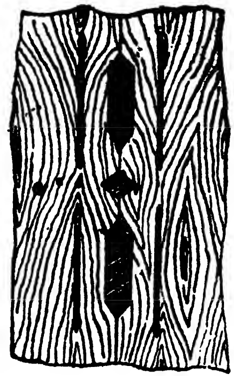


Fig. 3.

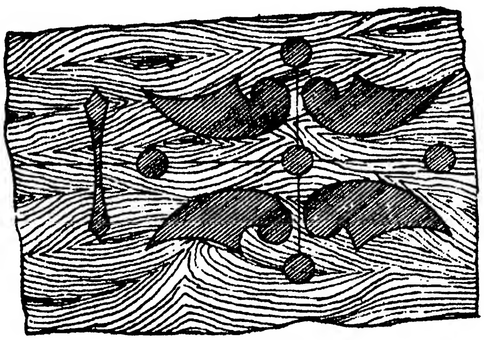


Fig. 4.

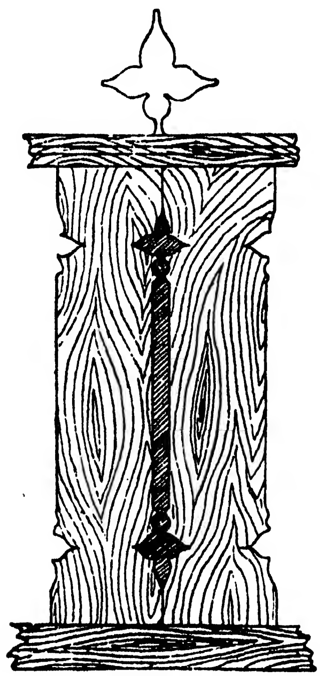


Fig. 7.

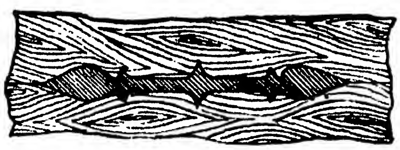


Fig. 6.

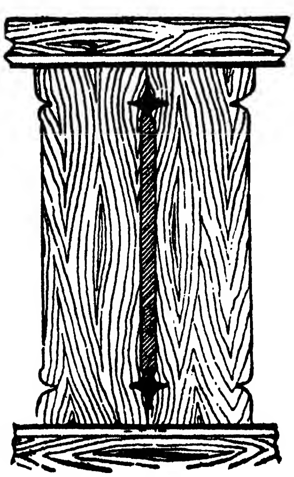


Fig. 5.

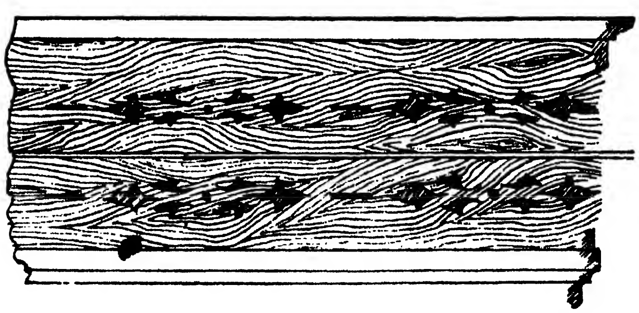


Fig. 8.

THE ORNAMENTAL WORKER IN WOOD.—*ELEMENTS OF CUT-WOOD WORK.*

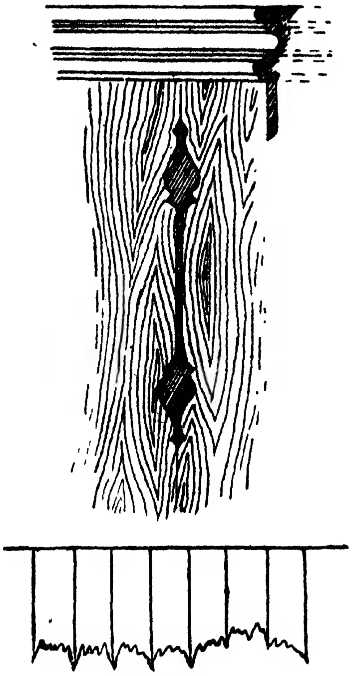


Fig. 1.

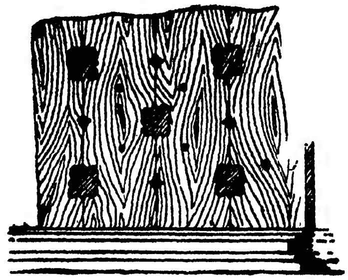


FIG. 2.

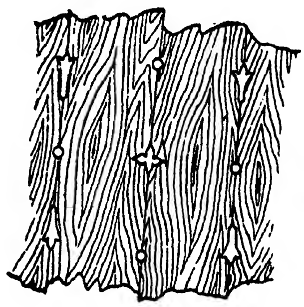


FIG. 3.

FIG. 4.

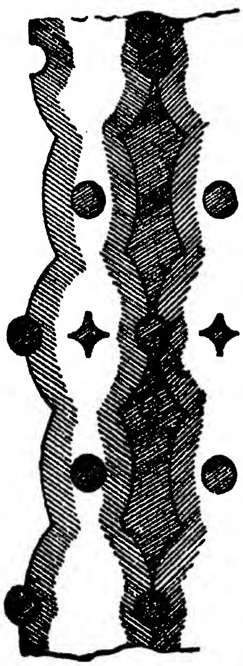


FIG. 5.

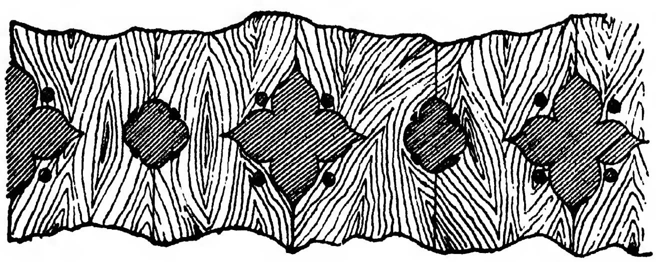


FIG. 6.

FIG. 7.

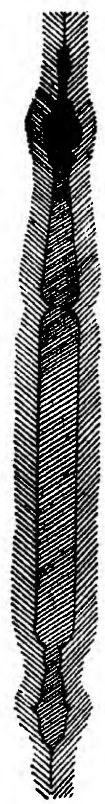


FIG. 8.

DEVELOPMENT OF ROOF

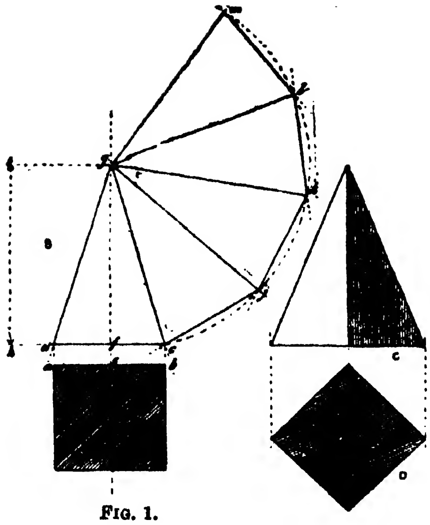


FIG. 1.

FIG. 7.

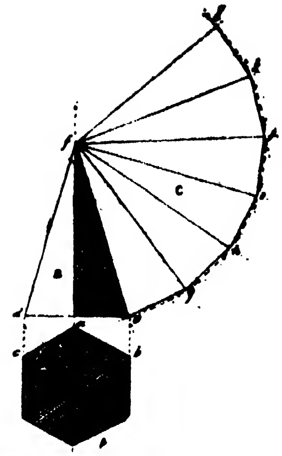


FIG. 2.

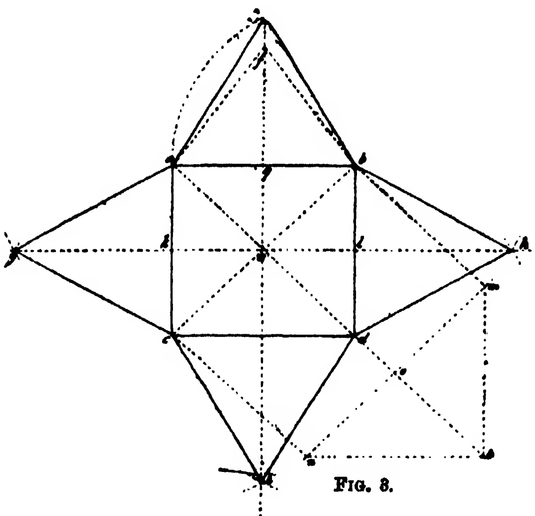


FIG. 3.

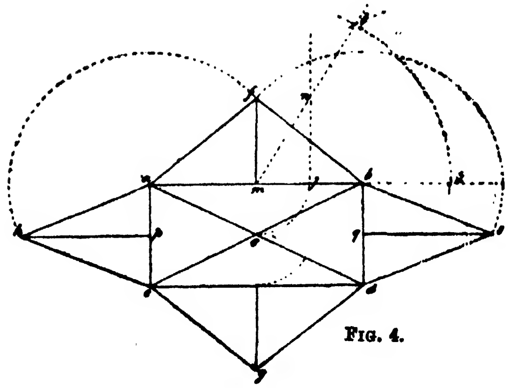


FIG. 4.

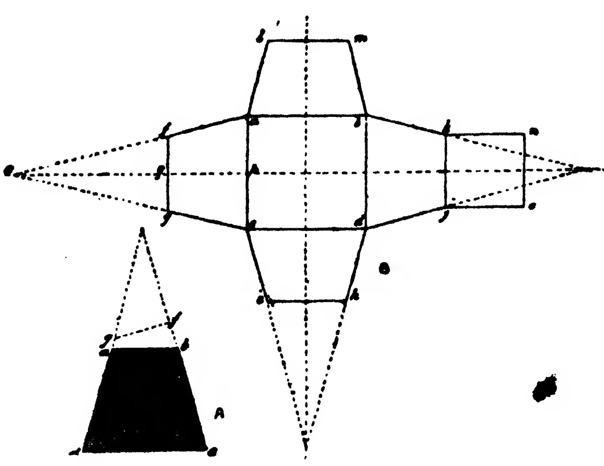


FIG. 5.

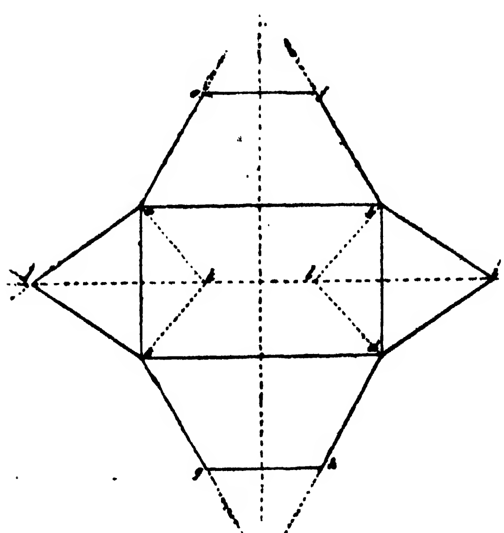


FIG. 6.

THE TECHNICAL STUDENT'S INTRODUCTION TO THE GENERAL PRINCIPLES OF MECHANICS.

Laws affecting Natural Phenomena—Matter and Motion.

CHAPTER XXXVI.

Properties of Bodies Relative, not Absolute.

At conclusion of last chapter, in treating of the porosity of bodies, we stated that the so-called solid particles have again their vacant spaces. These are formed, or owe their existence, to the polarity of the atoms composing the particles. And, as we have said, man does not know the limit beyond which the porosity of bodies does not exist.

The young reader will see how closely the properties of bodies we are now considering affect their treatment, and how by varying this a vast variety of effects or results in their relative constitutions or conditions are placed at the command of the workman, of the highest value in the mechanical arts of construction. The very fact that the "conditions" or what we call the "properties" of bodies are relative, which at first sight might appear to the student to be a disadvantage, is in reality that which places within the reach of the mechanical worker the power to bring about those changes in the conditions of bodies which he requires to enable him to do his work. And the youthful student may at first sight be somewhat puzzled at the statement made above, that man knows no limit to density, or conversely to porosity, or the point beyond which this porosity does not exist; inasmuch as he may have a difficulty to understand how it is that bodies are kept in any distinct or special condition, so that what is called a dense body is not in reality dense,—and what it is to which we owe certain conditions of bodies to which we give certain names, as porous or dense. But bearing in mind what we have said as to the purely relative conditions or properties of bodies, and referring to what we have given in preceding chapters as to the two great laws under which all bodies exist—namely, attraction and repulsion—it would appear that the condition of any body at any given time and under any given circumstances depends solely upon a balance between the opposing forces of attraction and repulsion existing at the time. How that balance is effected, or how it is, as we may say, secured, and how it is retained so long as the circumstances remain the same, we do not know—probably never shall know. We by no means ignore the value of what would result to man if he did know this mysterious "balance" of opposing and powerful forces, which gives us in one body a liquid, in another body a solid, and in a third an aeriform or gaseous substance; for the more clearly we know the laws which regulate and control the conditions of bodies, the more widely and practically will he be able to modify their action. And that there is a law which regulates the "balance" now noted, we have no doubt. But in the absence of a knowledge of what it is, it is enough to know that man by close and patient observation, and by no less patient trials and experiments, has discovered a vast variety of methods by which he can, so to say, so "disturb" what may be called the natural balance of the two laws which regulate the ordinary condition of bodies as to bring about changes in this of a kind the practical value of which in his daily work it is quite impossible to overestimate. And he is discovering new ways of disturbing this balance, and founding upon them new processes of great practical value. Many of the simpler methods of disturbing the natural balance of the constituents or particles or atoms of bodies are familiar to us all. We take a bar or rod of iron, and find that it will pass through a hole or aperture of a given size when it is cold, or, as we call it, in its "ordinary" condition, as lying exposed to the air. We place it in the fire; and on withdrawing it from this, so highly heated that it has in the dark a dull red heat, we find that it will no longer pass through or into the aperture. Here the "balance" is disturbed, and clearly in the direction of widening the pores or internal spaces, and by consequence causing the so-called solid particles to spread, so to say, outwards, thus increasing the bulk or diameter of the bar or rod; so that its bulk is now larger than the hole. But we can disturb the balance in another way. For let us suppose conversely that we have a hole of a given diameter or section, through which we find that a bar in its cold and ordinary condition will not pass, it being too large for the hole. In this case we take the bar and subject it to hammering upon an anvil; and in process of time we find on trial that after a certain amount of hammering we have so far reduced its bulk or size that it will now pass through the hole or into the aperture. Here we have obviously caused the particles to go closer together, lessening in proportion the pores or black spaces as supposed in our former illustration to exist. This capability of having their particles or atoms so disturbed that they move amongst each other and assume any position into which by a force or power they are made to take, and this without destroying or changing what we may call their mechanical properties, belongs to certain substances which are said to be malleable, or capable of having their form or shape—that is, their molecular arrangement or distribution of particles—changed without in any way changing or destroying or lessening the mechanical value of the substance or material. The word malleable means literally this (capable of being hammered), it being derived from the Latin *malleus*,

a hammer, from which, by the way, come our words "maul," to beat,—vulgarly, yet most appropriately, called "a hammering," and also "mall," the mason's hammer. It is not every material which is malleable, and those which are vary so much in this property that the hammering can only be carried to a certain point, beyond which any forcible disturbance of their particles changes their character and tends to weaken the substance. Some are so little malleable that any attempt to hammer them simply results in their being broken, or having their particles so effectually disturbed that they cannot be made to resume their original property. The two extremes of malleability may be said to be represented in the substances of gold, and steel in a certain condition, or slate. Gold may still be said to be the most malleable of all materials, it being capable of being beaten or hammered into leaves or plates of such inconceivable thinness that it takes considerably over a quarter of a million of them laid one upon another to give the thickness or depth of an inch. Steel, on the contrary, in a certain state may be said to be the least malleable, as on one attempting to hammer it, he will find to his disappointment that it will break as easily as if it were glass, which is the emblem of brittleness—that is, in *its* ordinary condition.

Fortunately for man and the wide and varied range of his mechanical work, iron and steel—prominently the "useful metals," and so called from this very circumstance—are, *in certain conditions*, malleable in a high degree. This would seem to be entirely contradictory to the statement just made as to the brittleness of steel, for example. But both steel and iron are very striking examples of the truth we have more than once alluded to; and that because it is one which the young reader should never forget or lose sight of—namely, that all the "properties" so called of the bodies or substances termed mechanical are purely relative, and entirely dependent upon the condition in which they are at the time, and on the circumstances under which they are placed. Thus, iron is, as we have said above, a metal possessed of such great malleability that it can be hammered or shaped into various forms, some of them, from the intricacy of their curves and the fineness of their lines, coming closely up to the graceful forms met with in trees and shrubs. Yet this malleability is only met with when iron is in that condition known as "wrought"—that is, hammered, squeezed, pressed — or "rolled," for rolling is squeezing or pressing; for when met with in the condition known as "cast" or "pig" iron it has no malleability, but may be broken or smashed up as one breaks up glass in its usual condition. So also of steel: in certain conditions, as soft and "untempered," it can, like wrought iron, be hammered and shaped at the will of the workman; but when hard and tempered, as in a cutting tool, it is very easily broken, as most of our readers know who have had much to do with the use of sharp cutting tools. Even the most thoughtless of youths would know almost intuitively that it would be utterly useless to attempt to alter the form of those tools by hammering them.

Condition of Matter capable of being Changed.

This capability of having their particles or molecules changed in position without having their integrity destroyed or their characters altered, possessed by many substances, of which the metals are the most striking examples, is of the greatest service to the mechanic. In virtue of it he brings about changes in the condition of bodies by altering the circumstances under which they are placed, and that as a rule by an application of some external force. Of this hammering—whether it be done by the muscular force of the body or by the infinitely greater, practically almost resistless power of the steam hammer, is an example. Compressing, condensing, squeezing or pressing power is another, which is quite different in its immediate effects, those being slow compared with the quick effects of the hammer blow or impact; but the results are the same—that is, the atoms are moved and so changed in relation to each other, compared with their original or, as we may call it, porous condition, that they come to lie closer together, and, occupying less space, give to the body the property we call density. Although this squeezing or condensing process is carried out in the mechanical operations of metal working to a very much less extent than is the process of hammering, which gives the density by impact or blows, still it is largely and most effectively used in many pieces of work. How suggestive to the young student of many points connected with the molecular disposition of metals is this fact in metal working: that we can increase the diameter of the bore of a cylinder to the required ultimate dimensions by making the last bore rather less than this, and by forcing into the interior—while the cylinder at the same time revolves—a steel rod or "condenser," this possessing the same diameter as the ultimate one of the cylinder. This, as it is forced longitudinally into the small bore, squeezes or presses the molecules of the metal, and by thus causing them to occupy less space than before, enlarges the diameter to the dimension required, just as if this had been done by simply boring; but with this remarkable difference,—that the metal in the interior of the squeezed, pressed or condensed parts is very much denser, and possesses less of the porosity of its original condition, although that might have been pronounced upon examination by the eye, or otherwise, to be anything but porous. And the other curious circumstance is this: that the

external diameter of the cylinder is not altered—that is, enlarged—which at first sight the student would suppose to be the natural result of the process; the molecules being pressed from the inside, naturally, as one would think, would squeeze or force the external molecules outwards. But the inner molecules are merely squeezed into the interstitial spaces or pores of the metal; which, while it enlarges the internal bore, does not affect the molecules of the outer rings of the cylinder, which remain as originally arranged. This condensation of the molecules of metal, or increasing of their density by a steady and a forcible pressure, is effected in more ways than one in metal working. In place of giving the squeeze or pressure by special mechanical means, it may be given by what is called natural pressure, or that of gravitation. This is obtained by the same method, and acts precisely on the same principles, as in the hydraulic experiment of giving great pressure to the sides of a vessel containing water by carrying up from it a long vertical tube, which is filled from the top with water, and by which what is technically called a "head" is obtained, and in proportion to the "head" (*i.e.* the height of the tube or the column of water it contains) is the pressure exerted on the vessel. The principle here involved is taken advantage of by the iron founder or moulder, in giving his "castings" a greater density than they might or would otherwise possess. This is exemplified in its simplest fashion by casting such articles as pipes or cylindrical vessels of greater length than diameter in a vertical position; and in a more perfect way by making special arrangements by which the molten metal passes down to the "casting" proper through a vertical channel, technically termed a "head" or a "dead-head," which extends a greater or less distance above the main body of the casting or its mould.

Those acquainted with the peculiarities of the steel trade know Sir Joseph Whitworth's system of compressing steel. This, reduced to its simplest elements, is the squeezing or pressing together of the molecules of the steel in a molten or fluid condition by pressure, this being that of the hydraulic press. While the "dead-head" of the iron founder gives a pressure of but a few pounds per square inch at the utmost, in the Whitworth process one of several tons per square inch can be easily obtained. For some of the very peculiar results obtained from this process, and the light which it may yet throw upon the molecular disposition of metals, the reader should consult the elaborate papers read by Sir Joseph Whitworth before the Institute of Mechanical Engineers and the Iron and Steel Institute, and the able discussions which followed their reading. The molecular disposition of Bessemer steel, now used in such enormous weights, which may be called porous, and in its most aggravated form giving the metal that dangerous peculiarity known as being "honeycombed"—that is, having throughout its mass, even in the very centre, large air cells—is one of the peculiarities which has raised a doubt in the minds of constructors as to the real constructive value of Bessemer mild steel, and is one to the avoiding or getting rid of which no small attention has been given. Apparently. from the very nature of the Bessemer process of steel making, the gases formed in the process have a great tendency to become what is technically called "occluded," or retained within the mass, and to the presence of these gases the air cells or honeycombed parts are due. These may be said to be large pores; and if the solid molecules surrounding them could be forced into them, or if the spaces or air cells which constitute those pores, so to call them, could be got rid of, so as to enable the molecules to lie closer together—that is, to increase the density of the metal —its constructive value would be obviously greatly increased. The object of the Whitworth process, above noticed, is to get rid of the occluded gases, forcing them outwards, and passing them through the outer molecules into the air, and further, by the mere force of the mechanical pressure employed, to squeeze the molecules at the same time very closely together. But the Whitworth process is but a slow, and it certainly is an expensive one, applicable chiefly, if not only, to cases where steel of a very high constructive value is required for special purposes, as for rifles, cannon, or ordnance—for which, in fact, Sir Joseph introduced his system of compression by hydraulic power. The chemist, the druggist, and many employed in various branches of the industrial arts, are well acquainted with the changes which take place in the constitution or physical peculiarities of a mass of liquid or semi-liquid substances by the simple process of stirring it. If the mass be made up of different substances, these, when first put into the vessel, may lie very loosely together—the mass being exceedingly porous, so to say. Stirring has the effect of bringing the particles togethor, so that they lie closely; and if a number of semi-liquid substances, of different colours, be used, the regular mixture of these will be made obvious by the process of stirring. If air bubbles collect, as they seem in some substances very readily to do, these will be got rid of—be squeezed, in fact, out of the mass till the whole becomes homogeneous. This simple and ancient process, with which every housekeeper is familiar, has been applied with decided success to the Bessemer steel making process. And although, like many simple methods of doing a thing very much wanted, it is being pooh-poohed by some who would very likely have given it a different reception had the object been gained by some more complicated and therefore clever-*looking* system; and

although it has not been universally or even very extensively used, still, wherever it has been employed, its success has been so marked that there seems little doubt but that the method, all simple though it be in principle, and not difficult to be carried out in practice, will be universally adopted—so long, at least, as the initial steps of the Bessemer steel making process remain as they are. It certainly speaks volumes in favour of the stirring system of rendering Bessemer steel dense and free from blow-holes or honeycombing, that Sir Henry Bessemer is himself altogether in favour of it—claims, indeed, that he years ago had anticipated the present invention of the stirring method by pointing out its necessity and showing how it could be done, but which circumstances prevented him from introducing into practice.

Mixture of Materials or Bodies.—Alloys.

How purely relative the term density, and hence, by consequence, the dense condition of bodies is, is well exemplified in the mixture of metals, as in the formation of "alloys," and in making different qualities of metals, as in the case of cast iron. The phenomena here do not come within the category of disturbances of the "balance" of the two laws which regulate all bodies, as explained in a preceding paragraph, but are dependent upon changes in the condition of the particles which come about, so to say, naturally, when a change of circumstances is made. This is familiarly illustrated in the case of a barrel filled with large and irregularly shaped stones. These, from their very shape, cannot lie closely in contact, but leave large spaces between them. Into these spaces we may, by shaking the mass of stones thoroughly, or by other means, pass or force pebbles. These again, being of different forms, will not lie close to each other, but will leave vacant spaces between them. Into those we can pass still smaller pebbles, these again forming spaces into which finally we pass sand,—when, as the eye may judge, there are no spaces into which material could be passed, although by employing sand of gradually decreasing fineness, and ultimately dust, we could get a still larger quantity of material into the vessel. Here we now have no longer a mass of exceedingly porous material, as with the original stones in the barrel, but a dense mass. This weighs now very much more than the original weight; for to the weight of the stones we have added that of the pebbles, and to the new weight thus obtained we have added that of the gravel, and finally to this the weight of the sand. Yet it is obvious that we have not increased the bulk or size; for the whole of the different materials are still contained within and bounded by the walls of the barrel. We have merely filled up the pores of the original substance—so to call the stones.

But the molecular disposition of mixtures of substances, as in the case of alloys in metals and of solutions in liquids, presents some very curious phenomena, specially worthy of the close attention of the mechanical student. In those the density is so increased that the bulk or space occupied by the two is actually less than the space which would be taken up by the two metals or fluids in their separate condition. A very marked example is furnished us by the alloy of copper and tin—90½ of copper and 9½ of tin—forming the metal known as gun-metal or bronze. Here the bulk or space occupied by the two when melted together is less by one-fifteenth than that which would be taken up by the two metals in their normal or ordinary condition. There can be only one conclusion in this case at which we can arrive: namely, that the molecules of the one metal which are the smallest or finest—which is the tin—must pass into and find room, to use familiar language, within the spaces or pores of the other and the coarser metal, the copper. And the same action must take place in the case of a mixture of oil and water,—of which if we take a quart of each, they will not make together two quarts, but so much less in a certain proportion than this bulk. We have also a parallel case in the dissolving of sugar or other like substance: we have, as the result of the mixture, always a less bulk than is really due to the united condition of the two under their ordinary circumstances. Here we may find a lesson as to the purely relative condition of bodies giving certain properties to which we give particular names. Popularly, the sugar being melted, it is said that it disappears, and is lost; but it is only that its condition is changed: the molecules or particles of the sugar are still there, only under another form; and by a certain process the original condition may be restored. In nature there is no such thing as actual disappearance: it is merely a change in condition; and in the great variety of physical substances there is an infinite variety of changes, which give rise to the purely relative conditions. The importance of "condition" the student bear in mind in all cases when he is considering physical bodies or substances.

The points connected with what are called alloys of metals open up considerations of the utmost value. An alloy is simply a mixture or combination of two or more metals; and by experimenting and trials of the resulting alloys man has succeeded in obtaining for his various purposes what practically are to him new metals, although they are made up of other old bodies. Numerous as those new metals are, and valuable as they have been for the purposes of the mechanic, there is every reason to believe that he will yet by a wider range of experiments discover alloys or mixtures still more valuable.

THE MACHINE MAKER OR GENERAL MACHINIST.

SPECIAL EXAMPLES OF HIS WORK—ITS LEADING TECHNICAL PRINCIPLES AND DETAILS.

CHAPTER XI.

IN relation to what has been said as to the value of observation, and how it is worth while to cultivate the habit of observing quickly, we may say that if the time never comes when you can take in at a glance, you will find nevertheless the immense practical value of being able to take things in—to make them your own—even if you have to give many glances, or find it but a slow process to "see" a thing accurately. Quickness will come in time, as use in nearly everything gives expertness, and time will show the value to the practical mechanic of this capability to see things accurately or to observe correctly, inasmuch as it is valuable in more directions than one. It is of great value in coming to a right comprehension of machines and structures which may have for business purposes to be closely examined. But it is of perhaps even greater value practically—in so far at least that the field for its exercise is not only so much more frequently opened up for use, but because it is very wide in its extent—in the case of the supervision and the general management of work. This ready faculty to see things as they actually are is in truth that which mainly constitutes the ability of a manager of works. Take the case of the manager of a factory in which there are at work not only many classes of machines—each class differing from its neighbour class—but in each class a great number of the same machines. Each machine is working economically only when in perfect condition and giving out the maximum of its efficiency. But this may be lessened to a very great degree indeed by something very minute of its kind which is wrong. A manager of ability, possessed of the faculty to see accurately, in going his rounds "takes in at a glance" what each machine is doing, and whether it is doing well. If giving bad work, he sees as quickly why it does so. Nay, just as likely as not his "quick eye" and "ready mind"—prompt to comprehend what the eye looks at or sees—tell him that something is wrong, some part out of truth, some part broken, etc.; and he does not therefore require to ask whether the work is up to the mark. He knows, under such circumstances of working, that it will not be so—that it cannot give good work. In this way a good manager keeps all the machines up to their full point of working efficiency, and this with, on the whole, remarkably little trouble on his part. The same holds just as true in the case of machine shops and engineering establishments; and it may be doubted whether there is any one thing which more thoroughly constitutes what is called a "clever manager" or foreman, than this same faculty of seeing things quickly. It is not that managers fail, as fail they often do, in keeping works up to the "paying point" from absolute ignorance of their duties. They know quite well what good work is, and if necessary they could "put their hand" to it and do it, and do it well. But what they fail in is, that they do not see quickly and accurately what is wrong, or indeed that anything is wrong at all. One manager would walk through a machine-room and repeat his so-called inspection several times a day, and yet see nothing wrong. This is done more frequently than it ought, to the great loss of the "concerns." Another would not get half through the same room before his quick eye and mind would see where the loss was arising. Now, as most of our young readers are doubtless ambitious to occupy the place of foremen and managers, and ultimately masters of works, we trust that they will see the pecuniary advantages which the faculty of accurate observation gives them. A little thought expended on the matter will enable them to see advantages arising out of it other than those we have named. One is that it tends, if not to bring about, certainly to strengthen and increase it.

Practical Results of Observation.

We have said that the practical truth of the definition that mechanical engineering is, in fact, the science of observation or of seeing, has been remarkably exemplified in the past history of mechanical work, which was based first upon the observation of natural phenomena displayed everywhere and always in the external world, and then by adapting those to the mechanical work to be done, and which, as we have seen, was the supplementing and also the supplanting of the class of work known as manual or pure handiwork only. And the more deeply and thoroughly the machinist studies the history of the science of machines, the more clearly will he see that all which are called mechanical laws are merely the adaptation in one way and in one direction or another of the laws of nature. And those laws, while viewing their almost endless manifestations, to which we are adding every day, the young student in machines will have some difficulty to believe are reducible after all to two only in number.

Now, those laws, although existing from the creation, remained for ages absolutely unknown; but what was done through their agency, or in other words the phenomena which in everyday life they exhibited, became to be known by man from a very early period in his history. But they became known only by their being seen and observed; and this observation was prompted, in the earlier instances, by something peculiar in a fact or circumstance striking—to use the popular phrase—some man more

thoughtful than others, and who applied what he had found out—literally what he had seen or observed—in some way or another to the doing of or the helping of his own hands in doing some of his daily work. All this was done in a very feeble way at first, and done, as there is every reason to believe, so seldom that it is fairly conjectured that some mechanical points, which are now so familiar to every one that their origin or discovery is never thought of at all—rather, indeed, as if there were nothing about them to discover—took centuries of patient observation and thought before they were added to the number of man's acquisitions, or to the evidences of what we now hear so much about as man's power over nature. But slowly as those facts and phenomena of natural laws were discovered, and made the property of all time by being handed down from one generation to another, still each fact or each thing which became known—however long the interval between its being so and the last which had been discovered—added to what may be called the general store. Each generation thus became richer than its predecessor; and as one now and another then was adapted to or made use of in what we now call mechanical aids, man became gradually more and more helped in the doing of the mechanical work. And with the increase of those adaptations or aids, the range of his work was widened, so that a large amount of labour was performed which no hands, however deft, no body however powerful, could ever have accomplished.

But what we wish the technical reader to specially note here is, that while this observation of natural facts and phenomena had resulted in the discovery of not a few mechanical contrivances, by which a larger amount of work was done than some are now-a-days disposed to admit; and although they were all of necessity dependent upon natural laws, it took so large a part of the whole period of man's existence in the universe, not to find out what was, but even to guess at, the nature of those laws, that their discovery, explanation, and proof was reserved for times so late that they came almost within and some of them absolutely within our own modern times. Up to the time of Newton—and that is not much over two centuries ago—there was no science, properly so called, of "physics"—that is, the science which explains the laws on which the facts or phenomena of natural objects depend for existence. What in the true sense of the term had been done in a scientific way was very meagre indeed, although every little done helped forward the time when the master-mind of the great Isaac Newton was given to the work of creating what was in truth a science of physics. Not but what generations before the appearance of Newton there was great talk of the "laws of nature"; indeed, the men of those early times who had much to do with the application of physical facts to the doing of work, or in the way of experimenting—for, in his earnest desire to know the reason why of things, man has ever been an experimenter, however rude—had little difficulty on the score of natural laws. They had an easy way of defining a law, or what they thought was a law. For example, if they noticed that certain effects followed the operation of a certain cause, this cause acting in like conditions, they at once were satisfied by stating that such and such an effect followed because it was a law of nature. Thus, take the operation of a common suction or draw pump. This contrivance had been in use for ages—so long, in fact, that the date of its discovery or invention goes back to those remote times so "hoary grey with eld" that history has no record of them. But seeing that, in every case where used, water always followed the plunger or piston, or sucker as it was often called, leaving no space or void between them, this was said to be owing to the operation of a natural law or a "law of nature," and its definition was put in these terms: "Nature abhors a vacuum." It is impossible now to say how long this so-called or supposed law satisfied men, both learned and unlearned: that it did satisfy for long, we know. But at last some one had occasion to use a draw or suction pump—as it was and is, although erroneously, termed—of much greater length, the well or source of water being of greater depth than usual; when, lo! after the piston or sucker had reached a much higher point than had ever been noticed before, the water somehow or another did not and would not follow, so that between the upper surface of the water in the pump barrel and the under surface of the piston or plunger, there was a space—and it must have been a vacuum, for neither air nor water existed in it—void or empty. The old law was here decidedly at fault. But the men of the time "were equal to the occasion." If the old law would or did not suit the new circumstances now so far as known, for the first time discovered, why, of course the old law must simply be got rid of and a new one made which would meet these circumstances. The process was simple in the extreme, and the men of the time would call this, which they had done in this easy way, no doubt, the "discovery of a new law of nature." This new law was thus formulated: "Nature abhors a vacuum, *but* she abhors it only up to a distance or a height of thirty feet,"—this last measurement being the height beyond which the new pump, which gave rise to the new law, would not draw water, however long and however vigorously worked. We do not here follow up the point and show how the true law on which pump working depends was discovered and formulated, which opened

up quite a new era in practical physical science. Suffice it to say that this ready and assuredly rough way of deciding upon a new law in order to meet new circumstances did not suit, or rather did not satisfy, one thoughtful man, and one eminently observant; who therefore took up this special case of the pump, and thinking the matter out and carefully experimenting, he finally deduced the great law of atmospheric pressure, which, as we have said above, opened up quite a new era in physical science. Did space permit, it would be in a measure easy to give numerous examples illustrating the point we have here named; and we may say, as an incitement to the reader to follow it up, that there is no chapter in the history of man more interesting than that which details the progress of physical science.

But we leave this tempting and to us ever fascinating line of study and research, to take up the more immediate points we have to deal with. But the direct application of what we have just given to those points will be at once seen when we beg the reader to note this: that while the practical man engaged in mechanical work is now vastly indebted to the scientific men who in modern times have formulated the physical laws on which all mechanical work is done, the scientific men could have done but little, and that slowly, if they had had to find out, that is, discover, all the facts for themselves. Many facts the modern scientists have found out—they are finding them out every day—but at the period at which the new era of machine science was introduced, the scientific men who brought it in or inaugurated it found ready to their hands, in helping them to deduce the true laws or theories, a vast accumulation of facts, the work of generation after generation of practical men who had lived before them, and had noticed them and stored them up, Again and again have practical men noticed a fact which has staggered them, but which has been laid hold of by men of science—just as in the case of the new fact as to the pump we above alluded to—and made the occasion of the formulating a law or a theory which in its turn has proved of eminent service to practical men succeeding. And this process is what is now going on around us every day, with this new feature as compared with the general circumstances of the days of old—that the scientific men themselves, now ever experimenting, become, so to say, the practical men of the olden times, who chiefly were observers of facts, and the facts or phenomena of those experiments again become the basis of working theories of high practical value to the technical world.

We have thus endeavoured to show how far the work of the machinist is one of looking at and out for things. And this looking at or seeing is itself a power capable of being cultivated to a high degree of excellence. But it must be cultivated in a right way, exercised in a right direction, for, as in all the work of man, there is in this a wrong as well as a right way of doing. What has to be said on the general habit the technical reader will find said in the series of papers entitled "The Technical Workman as a Student." And on what is there said we would draw special attention to the necessity to look all round a subject—that is, to leave no part of it unobserved and carefully noted. Leaving these remarks, which are given in the paper now named, to speak for themselves, we pass on to impress the reader desiring to succeed in the work of designing and constructing machines with the value of the habit of looking before so as to provide for all contingencies of mechanical work.

Providing for Contingencies in the Practical Work of the Machinist.

This habit is of vast importance to the machine maker and general machinist; and where one possesses this what may be called mechanical prevision or forethought naturally, or takes care to cultivate it till it becomes, so to say, a second nature, it has a high pecuniary value. Some engineers possess it in a wonderful degree. Some inventors seem to have looked forward so far, and have seen so clearly what was required, and what would be likely to happen in the course of practical working and experience, that it looks somewhat like the gift of prophecy. They seem to see at once what errors are likely to be made, what difficulties in working will be experienced, what the result will be of carelessness and prejudice, and as clearly as if they were recording the events of what is past in place of providing for the contingencies of what is yet wholly a matter of the future. Hence the inventions of such men seem, like Mercury from the brain of Jove in the classic fable, to spring into life armed at all points. Hence, in such cases very little is left for succeeding men to do, or for the inventor to do for himself, save in experiments in quite minor details, and these chiefly in the way of construction; the machine or system of machines and appliances remain for years precisely as they were first given life to by the inventor who has this gift of looking forward—of prevision.

How valuable, in a pecuniary sense, it is, and how it saves the inventor "no end" of work, and, what is infinitely more killing, worry, the technical reader will perceive at once if we remind him of what is the but too general course which mechanical inventions have to go through: the alterations made one after the other; this part taken out, another substituted, this motion giving place to that; breakdowns to be provided for, and the infinite variety of harassing little things which have to be encountered and met, to say nothing of the prejudices to be overcome, all of which may go on for a long time, and necessarily at

great expense in money, and at great expenditure in time, trouble, and worry, before the stage of perfection is reached, or that approach to it which in most cases the inventor can obtain and has to be contented with. And so numerous have been the changes made in the original conception of the machine, in bringing about this degree of perfection in its working, that the inventor finds its ultimate forms and parts in many respects different essentially from what he at first thought would be the case in reality.

Little more need be said as to the importance of this habit of looking forward to what may be required in work, for many exemplifications of it will occur to the thoughtful reader. It is obvious, for example, that its value is not confined to the perfecting of mechanical inventions, and to structures of all kinds coming within the range of practice; but it is just as valuable, although in another direction, in connection with the whole range of the details of daily work. The habit makes men provide for all contingencies of work, so that no time may be lost in waiting for materials, or accidents arise from the absence of certain appliances. Without this habit, indeed, it may be said with perfect accuracy that no machine shop or engineering establishment can be carried on and profits secured. Its value in the prevention of accidents may also here be noted. A very suggestive example of this is met with in a story in the life of Robert Stephenson, the celebrated railway engineer of the last generation. The story is not generally known, and is worthy of being told here for the lesson it conveys. As the reader will probably know, immense tubes or tubular girders carry the up and down lines of the railway which crosses the Menai Straits, dividing Anglesea from the mainland—the whole structure being best known as the Britannia Tubular Bridge. Those tubes were constructed on pontoons lying along the shore, and were floated to their places near the towers and piers or abutments which were to support them, at a great height above the water-way. The ends of the tubes were passed into recesses formed in the upright faces of the tubes, and they were gradually raised in these to their intended height by means of powerful hydraulic presses placed on the summit of the towers, the tubes being suspended from the presses by large chains. As may be presumed, every precaution was taken by the engineers to have all the parts of the lifting gear made with strength amply sufficient to meet all contingencies of lifting. Many engineers would have trusted to these, feeling perfectly assured that not only would the lifting gear be powerful enough, but so strong in its weakest part—for it is at that point in which the strength of a machine or part of a machine lies, paradoxical as it may appear—that no breakage could occur. Or, at all events, as the chances were as a thousand to one against a breakage occurring, many engineers would, with perfect ease of mind, have trusted to this chance. Not so Stephenson: he was too great an engineer to be forgetful of what other men would have despised, or at least have deemed to be of no value, as "little things," and one in no way disposed to trust to chance. Knowing well what would be the disastrous results of a breakage, which would allow such a monstrous weight as a tube was to fall freely even through but a small part of the great height at which they would ultimately be placed, he determined to provide for every contingency in the matter of the strength of the lifting parts. As the tubes were gradually raised by the enormous power of the hydraulic presses, the recesses were built up. In this way solid masonry followed the tube at each end, so that if a breakage in the lifting gear did take place, the height through which the tubes could fall would be reduced to a minimum. That minimum was but a few inches, for all that was required in the way of free space between the bottom of tube and upper face of masonry, which was built up in progressive courses, was what is technically called "clearance." Many engineers, having thus provided for the contingency of a breakage, with all its untold, yet in any case terrible and costly results, would have rested perfectly assured that human prevision could go no farther in the way of giving security. But here again the mind of Stephenson, like that of all great engineers, was equal to the occasion, and therefore in no way despised a little thing. However "little" it might be to some, Stephenson knew that with such an enormous weight in the tube, and with such a length and variety of parts making this great length up, each of which was in a measure a link in the chain, the length of the very shortest fall which the tube could take in the event of a breakage would be too great in reality, from the vibration produced in such a length of tube by the sudden stoppage of coming in contact with the hard, unyielding stonework carried up in the recess below it. Such shock might not do harm, but it might; and Stephenson, with true engineering caution, determined that the "might happen" should, if possible, be prevented or provided for. What was wanted in such a case was some body or surface on which the ends of the tubes were to fall so elastic that it would, so to say, "cushion" or relieve the shock, and yet so strong that it would not be crushed and destroyed. This was found in, and the contingency provided for by, the employment of blocks of wood. The stone filling of the recess was always kept at such a point that, on each lift being completed, space sufficient was left for passing in blocks of timber between it and the tube.

THE DOMESTIC HOUSE OR HOME PLANNER OR DESIGNER.

THE WORK OF THE YOUNG ARCHITECT OR BUILDER IN THE DESIGNING OF HOUSES FOR TOWN AND COUNTRY.

CHAPTER XIII.

A Street House on the "Flat" System, as Illustrated in Plan in Fig. 8 (p. 139, vol. iii.).

IN fig. 12 we give "front elevation" and fig. 13 "ground plan" of a row or terrace of street houses on the "flat" or one-floor system, adopted from the system in which there is no sunk area, as in figs. 9 and 10, and in which the ground floor forms what may be called the "self-contained house," as there illustrated, the difference being that in the system in figs. 9 and 10 there is a separate entrance direct from the street given to the "self-contained house"; while in fig. 13 the entrance is from the lobby *b b*, access to which is given direct from the street by the door *a*, and which is common to the house on ground floor and to all the houses in the flats above, of which there are three double sets, as shown in the front elevation in fig. 12. The row or terrace in this arrangement may be divided or separated from the pavement and street by garden or flower plots, which may belong to the tenants or occupiers of the ground-floor houses. These plots will be traversed by a paved footpath leading from the street to the door *a* of common lobby in passage *b b*. This path will of course be bounded by low parapet walls crowned with iron railings, separating it from the garden or flower plots on each side. Access to these will be obtained by entrance gates in parapet wall, those being under lock and key under the care of the tenants or occupiers of the ground-floor self-contained houses. The accommodation of these houses, and similarly of those in the "flats" above, is shown in fig. 13, "ground or street

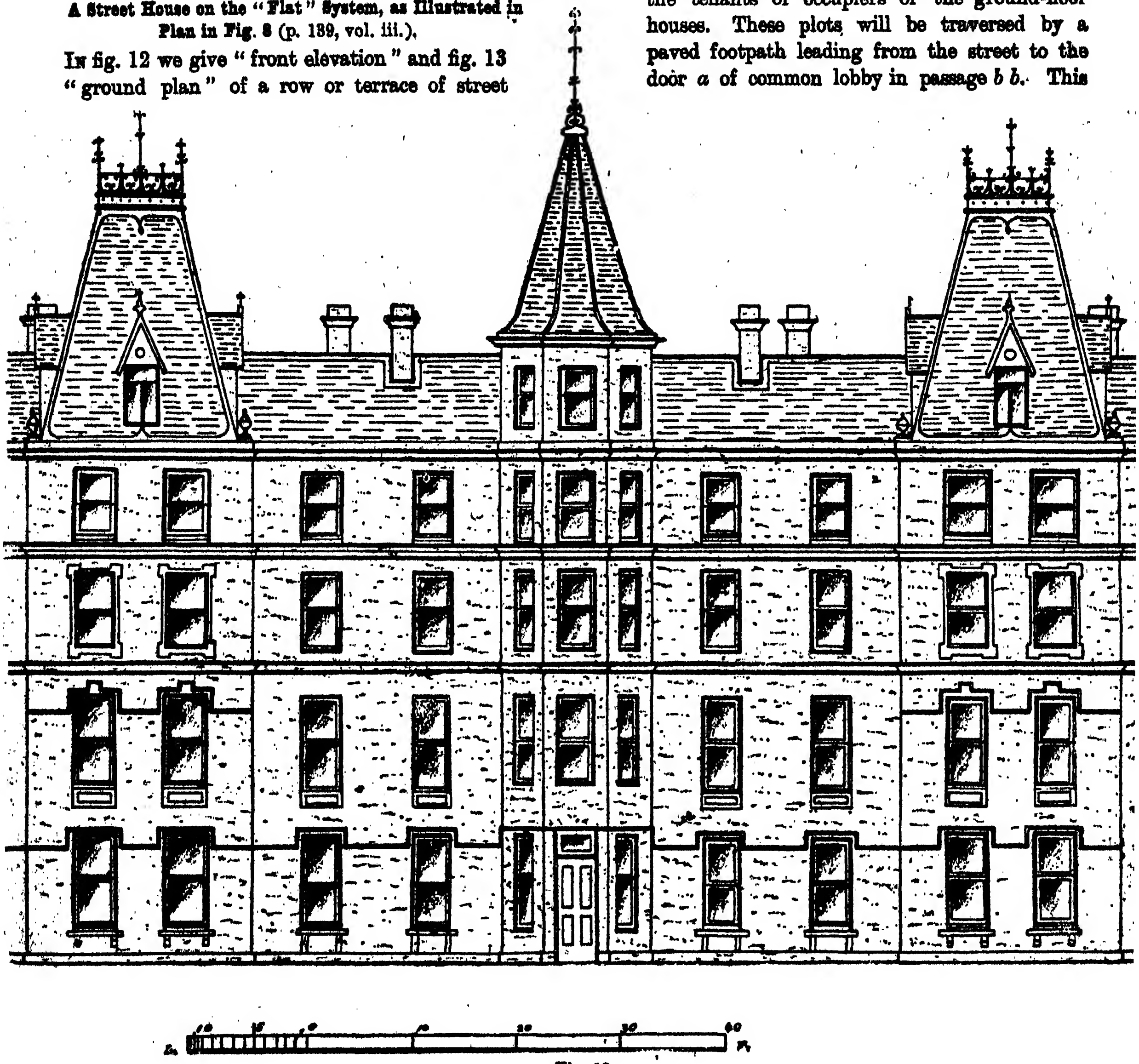


Fig. 12.

plan," in which *a* is the door to common "lobby" *b b* and "stair" *c d*, *e e* the landing. "Entrance door" to the house is at *f*, landing or "entrance lobby" *g*, and from thence to the "central lobby or hall" *h h*. The drawing-room is at *i i*, dining-room at *j j*. Between them, and entered from either of the rooms, is a "bed-closet" *k*, having at one side the "china closet" *l*, entered from central lobby *h h*. The principal "bedroom" in the front is at *m m*, alongside of which is a smaller "bedroom" *n n*, a back "bedroom" being at *o o*. The kitchen is at *p p*, with "servants' bed-closet" at *q*, coal place at *r*. The water closet is at *s*, and the "pantry" or "larder" at *t*, a "bath" closet being at *u*.

A system of arranging and building street houses is now common in the Scottish towns in the wealthier districts which is a modification, if it be not a direct copy, of the separate or "detached" system—in which each house, whatever be the number of its floors, is quite distinct in its entrance from the adjacent houses—which is universal all over England. In England, as we have seen illustrated in figs. 1 to 6, there may be several floors in each house. This style may almost be called Metropolitan, as it is more frequently adopted in London than in the provinces—where, however, in the large towns, it is common enough, especially in the older-formed districts. But in Scotland, with comparatively few exceptions, the style is confined to two floors—the ground, and upper or bedroom floors; although this last may be called the drawing-room floor, as it seems to be a habit in Scottish houses of this class to have the drawing-room on the upper and the dining-room on the lower floor. In this last there may or may not be a bedroom or bedrooms. Generally, however, the bedrooms are on the second or upper floor, as is also usually the case in England. In some cases this plan is modified by having the kitchen apartments on a basement floor, thus making the house virtually a three-storied one.

Street Houses in Rows (*continued*).

This class of house may be illustrated in figs. 1 and 2, Plate CLXI., and fig. 1, Plate CLXII. In this, as arranged, the street is designed to be made up of a series of blocks separated by short distances, the spaces between being occupied by gardens, half of each space being given to the end houses of two adjacent blocks. Each block is made up of four houses, two being placed in the centre, entering from the front; of the remaining two one enters at one, the other at the opposite end of the block. The internal arrangement or plan is as follows:—

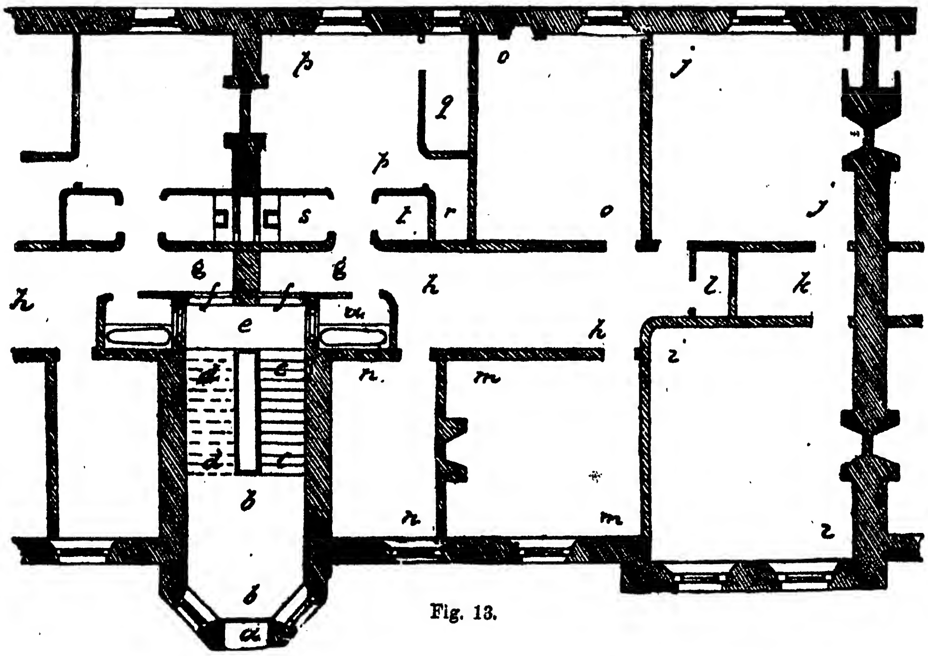


Fig. 13.

Fig. 2, Plate CLXI., is "ground plan" of two of the four houses of which each block is made up—one of the end and one of the central houses. In this, taking the end house first, *a* is the "entrance porch," *b* the "lobby," to right of which is a small "lavatory," *d*, and to left a "hat and umbrella stand"; *e* is lobby leading to "stairs" to upper floor, the return stairs being over the lobby *f f*; this leads to the "back lobby *g g*. The door to "drawing-room" *h h* is from side lobby *e*. The "dining-room" is at *i i*, with pantry or closet *j* off and entering from it. The "kitchen" is at *k k*, with "scullery" *l l* entering from it; *m m* "larder" or "store closet," *n* "china closet," *o* "pantry," *p* "bed-closet" for servant—or this may be enlarged by adding the space of the pantry *o* to it.

THE CARPENTER AND HIS TECHNICAL WORK.

Its Origin and Early Progress—The Principles and Details of its Practice.

CHAPTER XVII.

Trussed Beams (*continued*).

In reference to the use of pressure-distributing plates in the bolts and nuts used in trussed beams, we at the conclusion of last chapter (p. 101) pointed out the maxim of mechanical construction that all pressure should be distributed over as wide a surface as possible. Hence, if no pressing plate is used, the nut, as *t* or *x*, must be unusually large in cross-section—out of all ordinary proportion to the bolt or end of tension rod, so that a broad base is given to it. In place of the arrangement for central bolt and head shown in fig. 5, Plate XCVI., and fig. 10, Plate CLIII., and at *a d h* in fig. 4, Plate XCVI., the arrangement shown in last figure to the right of the upper diagrams is used for large trussed beams. In place of a bolt and head, as at *d h*, the beam as *i i*, diagram to the right at top of fig. 4, Plate XCVI., is embraced by the upper part, *j j*, of a cast-iron strut or bracket, shown in section in diagram below to the left hand at *i'' j'' j''*. The bracket or strut is continued downwards from *l*, where it joins the head *j j*, and is terminated at its lower end, *m*, by a part *n*, round the lower and rounded edge of which the tension rod *o p* is bent. This edge of the part *n* is hollowed out, as shown in side view at *n'*, so that a recess or hollow is made, into which the tension rod as *o'* passes, and is prevented from slipping sideways. In fig. 7, Plate XCVI., we give on larger scale the side view of a beam trussed in this way, in which *a a* is the beam, *b*, *b*, the struts or brackets bolted to the beam, as shown also at *k* in fig. 4, Plate XCVI., *c c* the horizontal part of the tension rod, bending upwards at either side, *d e*. In this form the outer and upper ends of the tension rods, as *d*, *e*, may be secured in a different way from that illustrated at *p p*, *u v*, in fig. 4, Plate XCVI. One method is illustrated in fig. 7 at *e f*, *f* being a cast-iron box or clip embracing the end of the beam, in the recess of which the beam rests as at *i'*, *j' j'* in fig. 4, and provided with a "snug"

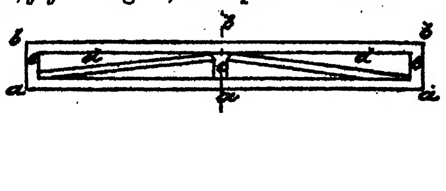


Fig. 86.

or projecting lug *f*, to which the end of the rod *e* is secured, the end being furnished with an eye through which a bolt is passed connecting it with the "snug" or lug, and secured by a nut.

Trussed, or as they are often called open trussed girder beams, are sometimes formed wholly of timber. In figs. 86, 87 (in text), we give various forms, of

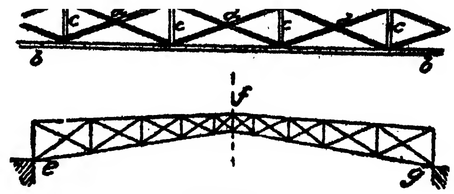


Fig. 87.

which we shall have more to say in a succeeding chapter. In fig. 86 the upper diagram is on the "king post" (see Roofs), the lower diagram on the "queen post" principle. These arrangements assume as a whole the forms of rectangular structures, as does also the lattice-trussed beam in the upper diagram in fig. 87. In the lower diagram the beam assumes quite another form.

Some Points connected with General Framework.

Having in preceding chapters illustrated and classified the various forms of joists used by the carpenter in the construction of framework, we now proceed to illustrate the various classes of that framework, or—to use the more frequently employed term—framing constructed of timber. Those classes of framing most generally used are exemplified or met with in house construction, and are known as floors, partitions, and roofs. But, in addition to these kinds of framing, there are several varieties met with in what may be called general work, such as the various forms of scaffolding and timber bridges, and that wide class of work in which the labour of the carpenter is combined with that of the mason and the engineer and machinist, as in harbour and dock work, canals, railways, and mining; and in the various classes of work in which the mason and the engineer or machinist are concerned. We propose to give one or more examples of each of these various departments of construction, so as to afford to the student of this important class of timber framing as wide a series of examples as our space will admit of, which will serve him in a directly useful way as a guide to his practical work of the future, either as examples to be directly followed, or as affording suggestions for designs of his own.

Previous to entering upon the description of these various classes of timber framing, we deem it right to give a few remarks on some essential points connected with the execution of framing. These remarks are chiefly connected with vertical framing, such as partitions, roofs, scaffolding, etc., but are more or less applicable to all kinds of framing, as floors and horizontal construction. In order that two pieces of wood which meet may give to each other a mutual

support without either of the two having a tendency to make the other turn on its axis, or, to use the popular expression, "on its side," or to "turn over," it is necessary that the axes of the two pieces should pass through a common point. It follows that the axes of two pieces of wood joined one to the other should be in the same plane, and that, with rare exceptions, their general plans or surfaces are in planes parallel to that of the axes, and consequently the faces of the assemblage or combination are all normal to these same planes. This system, whatever besides may be the forms which result from the combination of the pieces, constitutes a species of framing which takes different names according to the different positions in which it is employed.

If the joints were cut with rigorous precision, all the pieces of a framing erected vertically would work exactly in the plane of their axes, and the system would remain in a state or condition of complete equilibrium. But, notwithstanding all the care that may be taken with the work, we cannot hope for such perfection; besides, lateral thrusts created by the general building or structure itself exert upon a framing a strain or strains which tends to make it lose its proper form, and would inevitably overturn it if it were not supported by other parts which cross it, prevent it bending or leaning in any way, and secure for it perfect stability. Each framing representing a plane surface, it will be easy to draw it, pointing out on the drawing itself the actual length of the pieces which compose it.

In drawing the plan of any framework, the simplest and easiest process consists in imagining at first that the component pieces we desire to use are inflexible rods, possessing neither width nor thickness—that is, mere lines. We draw in reduced proportions, and separately, the partial plans of the different framings, by simple lines which represent these lines on the axes of the pieces. Among the figures which result from the combination of the lines in each drawing or framing, there are some which should in the first place suit the forms which the destination of the construction requires. Other figures, which are of no slight importance in the plan, should insure the stability of the construction. This drawing should show the position of the pieces of wood which should be common to the different framings which cross each other in the general design, if more than one. The principal lines of the plan being thus established, we add to it those which represent the auxiliary pieces, having as an object either to multiply the number of the numerous points which add to the rigidity of the framing, or to strengthen some parts which the flexibility of the wood would render too weak, or in short to distribute the strains or pressures so as to meet or resist certain strains, or transmit them to strong points capable of resisting them. When we have thus satisfied all the conditions, and in all the framings, by linear plans made and drawn (see "The Building and Machine Draughtsman") on a scale proportioned to the clearness of the details which we must afterwards add to it, we draw, by other lines parallel to the first, and on the same scale, the thickness of the different pieces, in order that they may have the strength required by their situations and the functions they have to fulfil, commencing with the most important or those which are the highest, and which have the least strain or the least weight to support. The drawings which this first work gives correspond to those which architects call plans and sections (see "The Building and Machine Draughtsman"), and are made according to the principles and practice of descriptive geometry. These drawings, figuring carefully all the necessary dimensions, to fix exactly the position of all the pieces and point out their general relations, usually suffice to guide the carpenter in forming the projected framework.

In general, the pieces of wood used in carpentry are not prepared with such precision that we can, as in other departments of construction, trace on their surfaces by rule and compass, or by templates or models of full size, lines which should determine their dimensions in length and the position of the joints. The pieces of wood are of a shape, size, and weight, which do not admit of moving them easily and turning them in all directions, as rendered necessary by the number of operations required. Besides, in drawing each piece independently of those which should be joined to it, we should introduce into the position and the shape of the different joints errors or mistakes which it would be almost always impossible to correct when they were placed *in situ* or in position. In the art of the carpenter there is therefore a method of drawing on the large scale similar to that employed by the shipbuilder, in which no joints are drawn with precision. He draws upon a large surface—in the art of shipbuilding it is called a "drawing-floor"—the design of the framing in full size. This drawing is often called by the name of "the lines" or the "working lines" of the design, as it contains only the lines which are strictly necessary; these lines are the axes of the pieces, or the reproduction on a large scale of the linear plan which we have already alluded to.

In order that the axes of the pieces should be exactly vertical to the lines which represent them on the "working lines," it is necessary that these axes should be drawn on the pieces of timber forming this framing. This operation is effected by means of a line. In a framing, as for example a partition, the pieces of which should be exactly square, the lines of junction should be straight and perpendicular to the plane of the axes of the pieces, and to each of their faces which are parallel to them.

THE FACTORY OR MILL HAND AS A TECHNICAL WORKER.

THE ORGANISATION, GENERAL DUTIES, AND SPECIAL WORK OF THE STAFF OF FACTORIES FOR THE PRODUCTION OF SPUN AND WOVEN GOODS—THAT IS, "YARN" AND "CLOTH"—AND THOSE CHIEFLY IN COTTON AND WOOL.—GENERAL DESCRIPTION OF THE VARIOUS PROCESSES OF MANUFACTURE.

CHAPTER XX.

Mill Management.—Bookkeeping (*continued*).

THERE is also another book kept, which is called the "cash book." This book shows all the amounts of money paid, and to whom; it also shows the amount of money received, and from whom. This is a very simple book, and easy to keep. It does not show at a glance, nor in any way whatever, how matters stand as to profit or loss, but it is a necessary book to keep; for though it does not give the idea that there are either profits or losses, yet when properly "entered" it is seen at a glance where moneys are not paid or not received. In entering the goods from the day book into the ledger the number of the day book is entered in the ledger opposite the account. This method of numbering makes it easy as a reference when required without any unnecessary loss of time. The same plan is adopted with the cash book and the ledger. We have said a cash book is indispensable. It is somewhat of a check, especially where any bookkeeping is kept by an orderly man. In making out invoices from the day book it is a common practice to write the initials I. D.—*i.e.* "invoice delivered."

Bookkeeping for cotton mills may be said, as a rule, to be on the "single entry" principle. It is called single entry, and well it might be, because it is simple bookkeeping, and in most mills it is found to be quite sufficient to keep the book by single entry. Where anything approaching order is carried out, it can be performed at a small expense, and references to anything can be quickly found. We know that at some spinning mills the books are kept by what is called "double entry." This is the case generally where a staff of clerks is kept.

The system of classifying goods used in the mill is a good one, and one which is frequently adopted, and with unmistakable advantage,—*i.e.*, certain articles are kept in account by themselves, as timber, oil, tallow, etc., etc. The object, principally, of placing each article under its own head is good for comparison of one account with another (this is often called bookkeeping by double entry). This is generally added up quarterly, or twice a year, and then at the year's end the full consumption of each article can be compared with that of the previous year. Should the consumption of the present year exceed that of the former year in any article, it at once calls for an investigation. This method has a stimulating effect upon those in charge, or the one who is responsible for the use or the waste which is made.

In the same way the comparison of weight turned off in yarn, and the cash in wages for producing that amount of work, is also investigated. These are simple methods, and ought to be fully carried out, otherwise it is almost certain that expenses will increase, even with the best of systems; but such means as above named at least arm us with "facts," and show how and where they exist, and this gives us the clue to the part which may be in fault. A division of wages (*i.e.* the preparing-room wages) can be taken from the gross wages and compared with former corresponding periods, and the spinning department can be so treated.

Those unacquainted with the business of a mill might probably determine that separate and individual investigations into articles which have been used in the works are altogether useless. Experience, however, proves how desirable it is that such minute search should be made. We know to almost a certainty that many careless workers of machinery, etc., have had to pay the penalty, and have come to beggary, partly from the lack of analysing the cost of each department and comparing one year's cost with that of another. It is obvious to us all that expenses will increase, in face of what can be said or done by the most careful managers. It is found in domestic or national management to be the same. It is seldom found that the production of any article lessens in cost, save and except where some improvement in machinery can be accomplished. This being a well-known fact, the best way to meet it is to investigate; and that can only be done by perseverance in a system of some kind, and where each and every part which requires money to carry it on with has its share of search. We are not inclined to recommend expensive methods, or systems so elaborate as to more than counteract any good than can be gained by them; that is not necessary—it is wasteful. We have seen how a love of multiplying systems, involving the employment of additional clerks, absorbs a large share of profits. Office-room, books, clerks (under and upper), and wages, are a considerable item in all works, and therefore simplicity, with of course completeness, is all that is required. We would say, in conclusion of this subject, that, though it may seem to those who have little or no real practical experience in the matter of keeping their books throughout, a spinning concern would appear of little moment, the great object in a spinning mill may be summed up in a few words, and apparently that would seem true: *i.e.*, to produce a good yarn and at as small a cost as possible. A prudent man would say, "Let me see it in black

and white; and let me have a system, though simple, by which I can trace the *facts* of this production daily. Let my method of examination be of that kind where errors can be pursued with comparative certainty, and thus let me have a chance to cure the disease, if there be one, before it takes too much hold of the concern, that it may be redeemed before it is past redemption." Bookkeeping is by no means spinning, or preparing for spinning. It is the nerve which gives warning of the danger, and might be called the telephone which speaks plainly and which does not often deceive. It is not the spinner, but it gives the result of spinning, etc. Success in all kinds of business is truly attained by taking care of small things; watching and guarding against every possible source of loss, no matter how trifling it may appear to be. In business nothing that is useful is trifling.

Weaving.—The Loom.

We have in a preceding chapter described in general terms the process of weaving yarn into cloth, and have detailed, more or less minutely, the duties of the weaver. We shall at this stage of our series of papers describe the mechanism employed in weaving, as the same form of machine, identical in principle, differing only in detail of constructive arrangement, is used in the formation of cloth from the yarn or thread of wool or the fibre of flax to the filaments of silk. And as we may hereafter have space to take up the woollen and flax manufactures, what we have now to give on the mechanical work of weaving will, in such a case, apply equally to those two important branches of our textile manufactures, and to the most important of them all—namely, the cotton—which has already in the preceding chapters of the present series been fully detailed.

Weaving is the art of combining two systems of threads which cross one another at right angles and entwine with one another. The one system, which consists of threads arranged to run parallel to one another throughout the whole length of the "piece" of cloth which has to be woven, is called the warp; the other one the weft or woof. The latter consists of a continuous thread or a number of threads which run through the threads of the warp backwards and forwards, or rather from right to left, left to right, right to left, and so on. Amongst goods, those like lace are distinguished by consisting of warp with the weft running diagonally, or of warp alone, or else of a single thread arranged in a wave or snakelike form, and woven into loops and meshes by being entwined in a peculiar way.

For weaving goods the ordinary loom has served for ages, and for plain sorts is still in use on account of its great simplicity; in figured goods, especially where the design is elaborate, the loom has become a most complicated machine. The description of looms and other machinery required for weaving, and used in ancient Rome, has made itself known to us through illustrations of Roman life found in certain places, one of which is represented in figs. 1 and 2, Plate CCLXXXI., the latter being the "shuttle."

Among the relics of the houses built on piles which are to be found near many of the Swiss and Italian lakes, and are supposed to be at least several thousand years old, explorers have come across woven fabrics so skilfully made that for a long time they were thought to be the work of a much more highly cultivated people than the dwellers in the lacustrine or lake houses, and were supposed to have come into the possession of the latter through trade (see fig. 3, Plate CCLXXXI.). We have succeeded in imitating these relics of the past ages with looms similar to the old Roman represented in fig. 1, Plate CCLXXXI., so that we can take it for granted that similar machines were used by these wonderful people who built their houses above the water. This inference is the more to be regarded as true, because in the remains of the pile-built houses balls of clay and round stones with holes in them have been found, resembling those used in the looms of the Romans for stretching the threads of the warp. In speaking about the construction of the ancient looms we must not omit the one which the Indians use to this day for producing their wonderful textures. In this particular kind of looms power is put into the background; the hand of the skilled workman alone is trusted. And just on account of this peculiarity Indian weaving has not sunk into a mere mechanical operation, but has remained an art, like it was formerly in other countries.

The Indian loom is remarkable for its striking simplicity, and the Indians probably use the identical looms that served their forefathers centuries ago. Their loom consists simply of two rollers or poles of bamboo and two tools. The tool upon which the weft is wrapped is at the same time both a shuttle and a rod; consequently it is made like a big knitting needle, and its length is rather greater than the width of the cloth. This arrangement the weaver carries under a shady tree, at the foot of which he digs a hole to contain his feet and the lower part of the loom, and then stretches the warp on the two poles, which are fastened to the ground by pegs at a considerable distance from one another. The upper part of the machine and the lever belonging to it are fastened to any suitable branch; to the lower part of the machine he fastens two loops, and by placing his shoes in these, forms the treadle. He does not roll the warp up, but stretches it at full length on the grass. Under such circumstances he cannot carry on his work in wet weather. Every evening he has to

carry his loom back to his hut. With us the weather would prevent such a system of weaving; but besides this objection, the desire to have a more substantial machine has caused inventors to improve and perfect the loom. In the western countries spinning and weaving were the principal employments indoors; in fact, in former times the whole clothing of a family and of their servants was nearly always spun and woven at home, and principally from flax and hemp grown on the premises. In Charles the Great's time special buildings were erected on the large estates, in which the female portion of the tenants carried on spinning, weaving, and the making of clothes. Besides the manufacture of linen the production of some excellent sorts of woollen stuffs was carried on on a very extensive scale; and both these branches of industry have maintained their importance, even after the citizen life in towns had reached its full development. Many towns, both in Germany and in the Netherlands, owe their prosperity to these industries. We can trace the manufacture of cloth as far back as the eighth century. The principal places where the manufacture of woollen stuffs and cloth were carried on were the country inhabited by the Frieslanders, the large tracts of land in the Dutch provinces suitable for the rearing of sheep, and the towns of Kempten, Zwolle, Deventer, Zutphen, etc. This industry, which was carried on in the towns themselves, soon spread to other cities in the Netherlands: in the fourteenth century it was at its height in the towns of Ghent, Bruges, Louvain, Brussels, and others. The disputes and even tumults caused by the quarrelsome weavers led to their migration; and cloth weaving was thereby removed to the districts near the lower and middle Rhine, the Danube, and the provinces of Saxony and Brandenburg. These quarrels and disturbances were the beginning of the decay of this important branch of industry in the Netherlands in the fifteenth century.

As spinning and weaving in those times were done entirely by hand, it can easily be understood how in in many towns so large a number of the inhabitants earned their living by carrying on this work in their houses. Many towns, in which the cloth manufacture has been carried on for centuries, still pursue this industry on a smaller or larger scale; but with few exceptions it has passed from the cottages to suitable mills. To illustrate the diversity and number of operations through which the cloth has to pass, it may be mentioned that formerly a piece of cloth coming from the weaver, in being napped, milled, raised, sheared, dyed and pressed, had to pass through different hands for each process, and under the most favourable circumstances could only be delivered to the buyer after a lapse of several months; whereas by using steam power and the newest machinery, it has been often shown possible to deliver goods made from wool received at the mill but a few days previous, and at the same time the cloth made by machinery is much superior to that made by hand. A similar state of things has taken place in the linen weaving: flax spinning has opened the way for linen weaving, and the latter has been greatly assisted by the Jacquard loom. The beautiful linen damasks (table cloths, for example), ornamented with large designs, which were formerly all made in hand looms (a special kind were used for making these figured goods), are now occasionally still made in hand-looms, but always with the Jacquard machine.

We now proceed to describe the loom such as is generally used, and refer in our description to the sketch in fig. 4, Plate CCLXXXI.

The Loom and Weaving.

The loom varies more or less in its dimensions according to what sort of cloth it is intended to make. The framework of the loom A A, *a a*, is about 1·8 to 2 metres high, 2 to 2·7 metres long, and, according to what stuff is woven in it, 1·2 to 1·8 metres wide, or sometimes even wider, and consists of a number of square pieces of wood running lengthwise and crosswise (*a a*) and fastened together as shown in the illustration, or often simply kept in their places by supports which are attached to the walls and ceiling of the room. In conclusion, we refer to the figure itself, which will be found to consist of four principal parts.

(1) *The warp beam with stretching apparatus.*

The warp beam, usually revolving on two iron pivots between the hinder columns, holds the warp which is wound round it. This warp is always being drawn off, passes over the breast beam C and the roller D, between which it is stretched, and can be fastened by its ends to the warp beam and the roller by means of small claws. If with a short loom it is necessary to stretch a long piece of warp in order to dress it, or to neutralise the influence on the direction (height) or tension of the warp caused by the difference of thickness between the warp beam and the breast beam (when the latter serves also as roller), these two beams are placed higher and lower, and in the place that they would otherwise occupy combing beams are placed to guide the warp and cloth, and are shown in the illustration by *b* and *c*. For this reason the warp beam is not unfrequently placed at the lower or upper ends of the pillars of the loom. The stretching of the warp can be arranged so that the end fastened to the warp beam remains fixed during the stretching, or if required can be slightly slackened. The former stretching is accomplished by the warp beam being held fast by a ratchet wheel *e* and a detent *f*, whilst the warp is being

stretched by an arrangement of cog wheels *g* attached to the roller D. The stretching is to be preferred for certain kinds of weaving. The degree to which the stretching is to be carried out is regulated by the fineness and closeness of the material or the fabric. Too much stretching impedes the insertion of the weft and the lowering of the treadle, and also increases the number of broken threads. On the other hand, if the stretching is not sufficient the weft works itself in too much, and the texture becomes loose and uneven. The warp which has already been divided into parts is kept in this state whilst in the loom by means of a number of pieces of wood called cross rods or gauges, and which pass through it at right angles. By means of these rods, over and under which the separate threads of the warp pass alternately, the warp is kept in its place, and if a thread breaks it is taken up again much sooner by their means.

(2) *The tackle with treadle.*

To be able to pass the weft through the threads of the warp in order to make the two combine together, the threads of the latter must be divided or separated so as to make a space for the former to pass through. This is attained by lifting up one part of the warp by means of flyers or shafts; in order to make a greater space for the weft, whilst one part of the warp is being raised the other part is depressed. The whole arrangement for forming the spaces, the shafts and their suspension, the treadles for working the shafts, and all the other machinery connected with them, are called the tackle, mounting, or harness. If in linen weaving the threads are not very close together, two shafts are quite sufficient to form the spaces. Through one shaft the first, third, fifth, seventh, etc., thread passes, and through the other the second, fourth, sixth, eighth, etc., thread, and each shaft alternately raises and lowers the threads running through it. The part of the warp that is raised up is called the upper shed, the part depressed is known as the lower shed or bottom of the warp; the size of the openings is termed the "shed" or "pass."

According to the nature or quality of the fabric to be woven more or fewer shafts are used; from 2 to 30 or more shafts can be employed. Each flyer or shaft consists of two slender sticks placed 17 to 22 centimetres apart, and taking up the healds or heddles with their ends. These healds, in order to last as long as possible, are made out of double thread of cotton or linen twisted and varnished, or else out of silk. In any case they are twisted or knotted into a loop or eye, or else hold a little ring (mail) of glass or metal, which is slipped into the loop. The healds have different names, according to whether they are attached to the upper or lower shaft—"sleepers," and "hangers" or "leaves."

The healds cannot be seen in the principal illustration, but several different kinds of them are shown in fig. 5, Plate CCLXXXI. The first, marked A, shows a heald in which the upper and lower parts are alike, and the warp passes through at the point where they loop into one another. The sleepers and hangers are not attached directly to the shafts, but fastened to a cord running along their upper and lower side. This heald is used principally for cotton and linen weaving in France, England, and North Germany. B is a double heald; each thread of the warp requires two such healds: the sleeper raises the thread to form the upper shed, and the hanger placed behind lowers it to form the lower shed. Double healds are very much used in Lyonese looms for weaving silk.

In the three following kinds of healds, C, D, E, the sleeper has an eye made by means of a plain or knotted loop, but the combination of the two parts is the same as in B and A. C is a kind of heald much used in Germany for weaving different sorts of goods. F is a form of heald which came into vogue in America, in which the leaf is omitted. The heald thread *a* forms two knotted loops (which in the illustration are represented open), the thread *b* passes straight through the loops, and when held fast by them forms the eye for the warp. G represents wire and tin mails, used principally for wool weaving, where thread healds would be too slight and would wear out too soon. H represents glass mails, used in looms for weaving silk and different sorts of damasks. In G the upper and lower openings are for the sleepers and hangers, the middle one is that through which the warp passes. In H three or more threads of the warp can pass through at once.

The tackle is placed behind the batten, and is attached to one of the shafts, *s*, by means of cords connected with one of the sticks, and running over rollers or over a cylinder, *t*, revolving on pins and fastened to the upper stick of a second shaft, which balances the first in such a way that as one rises the other is lowered, and *vice versâ*. The lowering of the shafts is effected by means of a treadle or footboard, *r r*, which is also connected with the lower shaft by means of cords fastened to the sticks. The number of treadles for weaving linen or similar goods is two. Different and also compound arrangements of treadles used for weaving other kinds of goods will be describd when speaking of these goods.

(3) *The batten with reeds and shuttles.*

The reed inserted in the batten keeps the warp constantly at the same width, and to it the weft, which is woven in by means of the shuttle, is at-

tached. The closeness and evenness of what is woven depends on the strength and evenness of the attachment. The batten *h i k l*, fig. 4, Plate CCLXXXI., is a wooden frame, rather wider than the breadth of the warp, and is fastened to the upper cross-piece *h i*, called the batten beam. This beam possesses pins which work in suitable grooves, *m*, in the upper longest joist of the loom, and have free play in them. To the projecting ends of the batten beam are fastened the two arms or shafts *h l* and *i k*. To these arms, and placed above the warp, is the pull-to or cape, and underneath the same is the heavier cheek, which is often weighted, as its work is to assist the oscillating motion of the batten. Between these two parts, in which there are long slits, the reed (slay, sley, stay) is placed. This consists of two pieces of wood 1—1·2 centimetre in thickness, which, according to the size of the shed or pass, are placed 5—15 centimetres apart, and are connected by two other pieces of wood at the ends so as to form a frame, inclosing the dents, splits or reeds, which are made out of flattened steel or brass wire, or else out of small tubes. Upon the number of threads in the warp, and how many of them pass between each pair of splits or reeds, the number of splits and the closeness of the reeds depends. A certain number of reeds or splits is called a treadle, and the breadth of the reed is reckoned in treadles. Each treadle contains 40—48 threads.

The upper side of the cheek, which slants off a little, forms the path for the shuttle, which is shut in by the shuttle box at the ends. The shuttle most used for hand-loom weaving is made out of box wood, sometimes out of palm-tree wood, apple-tree wood or beech wood; it is 15—40 centimetres long, 2—5 centimetres wide, and 2·5—4 centimetres deep, terminating at the ends in conical metal points in order to pass through the spaces easily. Two kinds of shuttles are known,—the hand shuttle and the flying shuttle: the former is thrown by the weaver's hand through the open space, and for this reason is slightly curved lengthwise; the latter is thrown forwards and backwards by the drivers or triggers in the spool box, to which are fastened the cord *o* and the whip *n*. In addition to not being curved in its length, the flying shuttle possesses two small rollers placed at right angles to its longest axis. These rollers project very slightly beyond the bottom of the shuttle, and work very easily, so as to assist the shuttle to slip to and fro along the lower shed, or along its path. The flying shuttle, which is now so universally used, was invented in the year 1733 by John Ray of Bury, and is sent alternately from left to right through the opening of the warp by means of a cord passing through a whip *n*.

The middle portion of the spindle is hollowed out, in order to hold the fixed or movable axle called the spit. The spools placed in the spindle are either loose shuttle cops or fast shuttle cops. The first kind is put loosely on the spit, and its rate of revolution is usually regulated by a slip of metal pressing against it. The fast shuttle cops are placed firmly on the spit and do not revolve, but the cotton is easily drawn off, and passes through the rounded end of the shuttle. The spools themselves are made out of wood, paper, or even reeds, and the latter are often tied at the ends with tarred thread, to prevent them from splitting. In the side of the spindle there is an eye of glass or porcelain, to allow the thread from the spool to pass through.

If the weft is to cause a change of colour or material in the fabric, several shuttles can be used one after the other, or changed at will, by means of the double or changing batten or drop-box motion invented in 1760 by Robert, son of the before mentioned John Ray. For a long time Vincent used this kind of changeable shuttle for putting twelve different colours in the weft. Instead of the shuttle box, which is divided into compartments, being raised to the path of the weft every time the colour is changed, and then lowered again, there is now an arrangement by which the box can be made to move or turn horizontally.

(4) *The front roller or breast beam with winder or regulator and stretching rod.*

When the front roller is also the cloth roller, it is provided with an appliance for rolling up the stuff as it is being made. In this case holes are bored crosswise through the roller in order to receive spokes by which it can be turned round, or else two crossbars are fitted on to the end for the same purpose; in both instances the roller is provided with a ratchet wheel and catch, to prevent it turning the wrong way. In fig. 6, Plate CCLXXXI., the cross arms *p* are attached to the breast roller, which is situated low down and serves as cloth roller. It is evident that if the cloth is not wound up regularly, it will visibly shorten the oscillations of the batten on account of its width. To insure a regular and uninterrupted winding up of the cloth, a regulator is used. This regulator is universally constructed on the following principle. At each movement made by the treadle or by the batten a toothed wheel is moved, and, by means of intermediate wheels or a screw, acts on a wheel attached to the cloth roller and makes the same wind up exactly the quantity of cloth woven by each insertion of the weft. The top of the shed is therefore always in the same line, and the room for the batten to move in is always the same size. To wind up the cloth on the front roller, it (the roller) is made to revolve in the direction of the winding by means of weights suspended to it, and, in order to hold the cloth fast and pull it along, the breast

roller has a rough covering such as fish skin, or sand glued to it, or spikes driven in, etc.

Every time the shuttle turns round it pulls in the outside threads of the warp, causes a diminution in the width of the fabric being woven, and forms an uneven and wave-shaped selvage. To remedy this evil it is customary to employ a stretcher or stretching rod, *q*. This tool is like a ruler, but made in two parts so that it can be shortened or lengthened, and has at the ends, which are about 5 centimetres wide, sharp spikes which fix themselves into the selvages of the cloth. The stretcher is always placed as close as possible to the batten. It is rather longer than the width of the cloth; and after being fixed in the cloth it is moved back and refixed when a small quantity has been woven. Even this work is performed by a mechanical or self-acting stretcher, and is done continuously and without any assistance from the weaver.

Operations Pertaining to Weaving.

After having examined the loom, as in preceding section, we turn now to the preparations for the weaving itself, and shall be better able to say something more about certain subjects than we could well do in describing the loom.

The preparations for weaving refer to both the warp and the weft. The preparations connected with the warp are: spooling, winding, beaming, dressing. In hand-loom weaving these operations are carried out by hand, but in steam or power-loom weaving they are principally performed with the assistance of machinery. The yarn coming from the spinning mill is not always delivered on bobbins; as a rule it has to be transferred from hanks to small tubes, from which it can unwind more easily, and this operation is called winding or spooling. The object of spooling is to wind the warp and weft on spools, which serve for winding the warp or for placing in the shuttle; for the latter purpose the pin cops or cops coming from the mule are not as a rule used right away. The spooling can be performed in a hand spooling machine or else in a winding machine. In the former only one spool is wound at once, but in the latter from 6 to 80 and even more, which are placed in one or two rows or in a circle. Particular care must be taken, in winding the weft in the hand spooling machine, that the layers of thread are placed so that when being interwoven with the warp each winding comes off easily without disturbing or pulling off the layers lying near to it. Loose and fast shuttle bobbins are smaller than warp bobbins. Cotton, linen, and woollen weft is often used wet, because it is then softer and more pliant, allowing itself to be woven closer in the fabric, and in cotton goods more evenness and smoothness is obtained. To wet the weft it is either wound wet or else the spools are placed in water before being used.

In spooling, the cotton or silk yarn is placed upon easily revolving winders, and the ends of each lea fastened to the spools, which are made to revolve by means of endless cords connected with a drum which is driven by a treadle, or else by means of the friction from discs or cylinders upon which the spools stand or lie. With good yarn the spools make about 300 revolutions per minute. In order that the threads may be wound regularly on the spools, the yarn is drawn through small glass rings in a wooden lathe which moves from side to side or up and down, and so takes the yarn from one end of the spool to the other and causes it to be wound spirally. The movement of this lathe is attained by means of a heart-shaped disc or by some other similar arrangement.

After the warp has been spooled the number of threads required for weaving the fabric (the number depends on the width of the fabric and upon the closeness of the warp in it) are wound up so as to form a system of threads lying perfectly parallel to one another, and through which the weft can be easily passed. This operation is called

Winding, also Warping and Warp Winding.

The machine for carrying out this work is called a winding frame, and consists of a perpendicular reel with eight to sixteen arms, rather over two metres in height and three in circumference. At the lower end of the axle of the winding frame a metallic pin is inserted which works in an iron socket; the upper end of the axle stands out considerably above the top of the frame and fits into a collar fixed to the ceiling of the room. This arrangement allows the frame to revolve freely. At the top of the frame three nails or pins are placed, called cross or traverse pins; their work is to place the ends of a number of threads (of a set of leas or half-leas) on to the outermost nail, and then to place them crossed or plaited, half over one nail, half over the other; so that one half passes over the second and under the third, the other half under the second and over the third nail. Then, when the frame is made to revolve, all the threads as they are wound round unite to form bands similar to the slivers spoken of before, and form a spiral always going lower; the bands then pass over (or under) the first of two pins situated near the foot of the frame, round the second one, and then back again under or over the first. When, by the frame revolving in the reverse direction, the bands are wound up to the top again, the crossing, as before explained, is done over again, and the operation is repeated until the required number of hanks have been wound. The threads, which are spooled together, generally come from spools placed horizontally in the hank (or creel), and pass through a glass eye fixed in a guiding jack, by which the workman can regulate the winding of the threads upwards or downwards.

THE ORNAMENTAL WOOD WORKER AND DESIGNER,

In Carpentry and Joinery, chiefly for Exterior Work.

(BEING ONE OF THE SUBSECTIONS OF THE PAPER ON "FORM AND COLOUR IN INDUSTRIAL DECORATION.")

CHAPTER VI.

Further Examples of Combinations in Ornamental Effect Suggestive to the Young Designer.

THE principle of combination of straight-lined perforations or apertures in connection with the elementary forms of this class may be further and usefully illustrated as leading the young designer of work of this kind to think out combinations; for if he does so well in simple, he will be so much the better able to cope with the difficulties of the more advanced subjects we have to put before him. Let us take the triangle or three-sided perforation, as at *a* in fig. 10. By arranging the triangles in line, as at *a b*, speaking two sides of it, as the base is wanting—by the proper inclination of two rectangular apertures or slots, as *m n*, meeting in point *o*, arrange those as shown at *p p*; and the pupil will perceive that as an arrangement of simple straight-lined apertures there is a pleasing variety obtained, and which gives a nearer approach to what is popularly called a "pattern," although it may not be so readily designated by the higher and more pretentious term "design." Yet design it is, if that word—as it assuredly does—involves a "purpose" or design with a definite object in view. (For some remarks upon the term "design," the reader is referred to the chapters under the heading of "The Cabinet Maker.") In place of having the central space in *p p* solid, it may be opened up by perforations as at *q*; and if *p p* is to be a "repeat" along a band, the repeats should be separated by some simple perforation, as at *r*. Where a large-sized opening is required, the arrangement of the triangle known as the isosceles (see *b*,

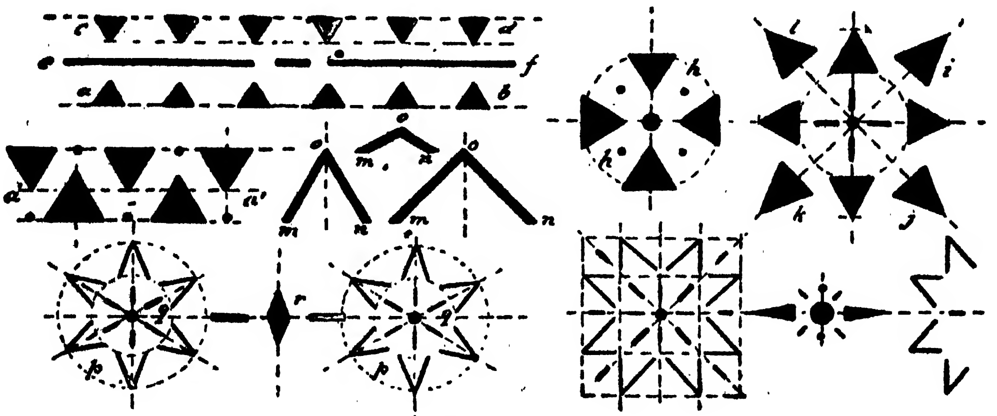


FIG. 15.

and giving another line, as at *c d* in fig. 15, so that the apices or points approach each other, the bases being at the lower and upper sides of the band and parallel thereto, a certain pleasing variety of perforated band may be obtained; the central space between the two rows or lines of triangles being opened up with simple perforations, as at *e f*, or the triangles may be alternated as at *a′ a′*. The triangles may be arranged in concentrated or closer combination to form a "centre part," as at inner part of last diagram to the right hand at top, the bases being towards the central point—or as at *h h*, where the apices are towards the centre. By introducing triangles placed with the bases in an oblique position, as at *i j k l*, another variety is obtained.

As showing the pupil how often a good effect, or at least what as a new feature may be obtained, by simple means, and as inducing him to think out even such an insignificant form as a triangle—not much artistically in it—we give the following. In place of cutting the triangular space fully out from a triangle—strictly fig. 10) may be used. The simple perforations as at the right-hand lower side of fig. 15 will add variety and relieve the formality of the arrangement. But formality or precision is always a feature of all straight-lined forms, and can only be got thoroughly rid of by graceful curved lines.

Further Examples of Straight-lined Ornamental Arrangement.

Still following up the elementary forms given in fig. 10, as conveying excellent practice to the pupil in "combination" of straight-lined forms, and giving him the best introduction to more complicated work, we take the other forms in fig. 10. Not much can be done with the "square," as at *i* in this figure. If used by itself, or in line, it should never be placed with its sides parallel to one and at right angles to the other side of an object, such as at *i*, but placed diagonally, as at *k* in fig. 10. Placed thus, and in line, as at *a b c*, fig. 16, and by spacing the "diagonal squares" out, as at *d e f*, and placing simple perfora-

g, a still greater variety or pleasing effect is obtained. By disposing the squares in a double row, as at *h h*, *i i*, another effect is produced, which may be added to by the introduction of simple circular openings between. In this arrangement the openings are said to be "interspaced" or "alternated," the lower row of squares being arranged so that each

Where this diagrams in the preceding figure, 16, to make a form is used in constructive arrangement, this is shown "centre-piece," one method of obtaining in fig. 3, in fig. 1, Plate XLV., another at *a* arrangement at Plate XLV., and a still more pleasing arrang a band *b b* in same figure. When spaced out along being left at equal intervals, the intervals, in place of

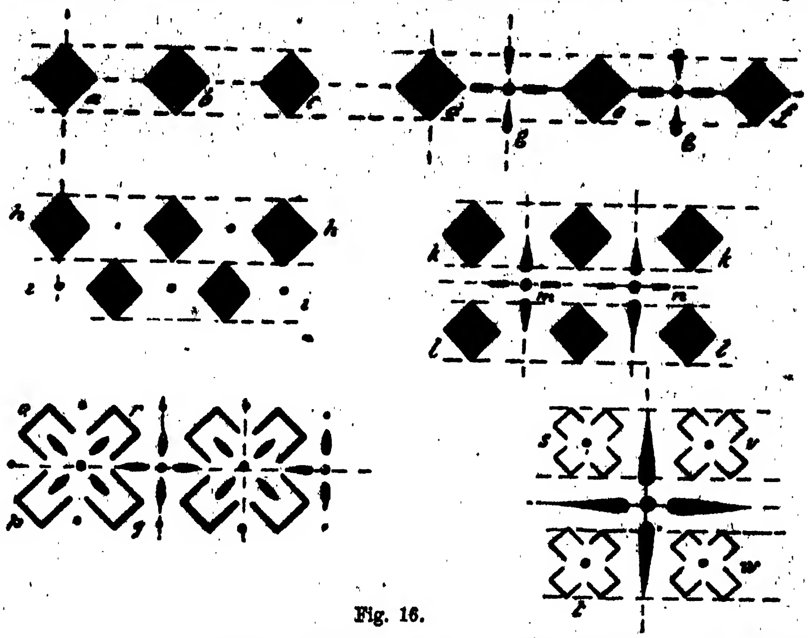


Fig. 16.

square in it occupies or falls into the space between two of the upper row. The converse arrangement is shown at *k l*, where the points of both rows approach or are opposite to each other. The spaces between may be left solid, or better still opened up as shown at *m* and *n*. The square may be used in part cutting to

solid, may be opened up with some simple arrangement of perforation such as at *d d* or *e e*. In figs. 4 and 5, Plate XLV., we give figures combining some of the elementary forms already given. Figs. 2 and 6, Plate XLV., are other arrangements of angular lines for perforated work. Of course the workman will

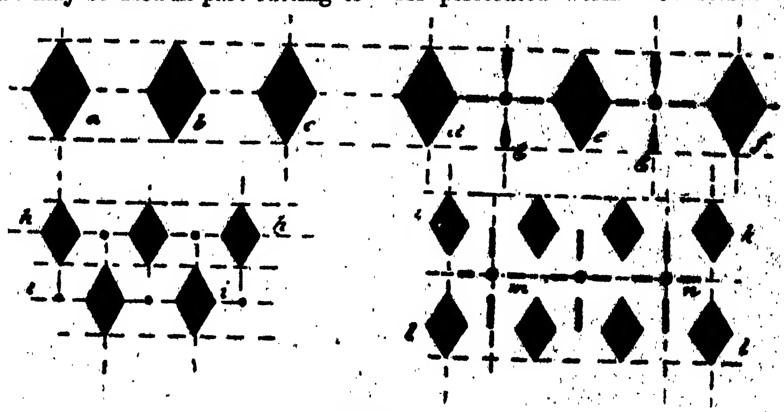


Fig. 17.

form an opening, as at *o p q r*, and this form may be combined, as at *s t u v*.

The combinations which may be made out of the elementary form of straight-lined figures, as in the *d e e* or *h f g*, fig. 10, are illustrated to some in fig. 17. The dispositions of this figure in

have, in cutting out these spaces, to stop short at certain points; this gives a solid part to hold the whole together. If the spaces were cut continuously the parts would simply be cut out, leaving a large hole. This stopping short will be noticed in diagrams we have given, as it will be

THE BUILDING AND THE MACHINE DRAUGHTSMAN.

CHAPTER XXVII.

Contrivances connected with Motion.—The Cam (*continued*).

WHERE a "cam" is desired to give a motion fast or slow, its velocity to be accelerated during a certain period and to diminish towards the end of its stroke, or travel so as to attain the same speed it had at the beginning of the stroke and then again to go on towards the point where the speed or velocity is quickened, a modification of the heart-wheel in fig. 1, Plate CXXXIV., is used. This is illustrated in fig. 2, Plate CXCIV. This cam cannot be worked in a frame, but is used only with rising and falling rod, with friction wheel, as at *d e* in fig. 1, Plate CXCV. The illustration to be now given is shown with the rod at the lower side of the cam, the wheel of the rod as at *b*, but this is done simply to give the young draughtsman an exercise in setting out the lines in a direction opposite to that in fig. 1, Plate CXXXIV., which is the normal way of delineating a cam of this kind.

In fig. 2, Plate CXCV., let *a b* be the length of travel or stroke of the rod, as *d e* in fig. 1, Plate CXCV., and *b c* the diameter of friction wheel, as *e e* in fig. 1, same Plate. Set off from point *c* a distance, as *c d*, giving sufficient thickness of metal between the inside point of cam curve at *c*—which is the point of commencement of the curve required—and the inside line of eye or centre *d e*, through which the shaft passes which carries the cam. From *d* set off half the diameter of the extended centre or eye of cam. In the "heart-wheel cam," as in fig. 1, Plate CXXXIV., the points of the curve are all found by the intersection of circles with the radial lines, the distances between the circles being all equal. The points of the path taken by the rod, as *d e*, fig. 1, Plate CXCV., or by the frame of the cam if it works in a frame, are exactly proportional to the angular velocity of the cam. In this case, if the velocity or speed of the shaft *p*, fig. 1, Plate CXXXIV., be uniform in a given time, the rectilineal movement of the rod, as *d e*, fig. 1, Plate CXCV., is also uniform. But in this case now being illustrated in fig. 2, Plate CXCV., the motion is not uniform, and in place of the generating circles of the curve being at equal distances, as in fig. 1, Plate CXXXIV., they are unequal, as shown at points 1, 2, 3, 4 and 5 in fig. 1, Plate CXCV. These distances are to be decided upon so that they will be proportionate to the acceleration and to the lessening of the velocity of the cam motion at the points of the travel or stroke of the rod, as *de* in fig. 1, Plate CXCV. Having assumed those points, as 1, 2, 3, 4, 5, fig. 2, Plate CXCV., from centre of circle *d*, with radii as *e* 1, *e* 2, *e* 3, *e* 4, *e* 5, describe circles shown dotted in diagram. Draw through the points *a, c, e*, the diameter *a k*, and divide the semicircle as *a h k* into the same number—six in the drawing—of parts as the line *a c* is divided into; and through the points *f, g, h, i* and *j* draw radial lines, as shown. These are so lettered to prevent the confusion which might arise by numbering points *f, g, h, i, j* as 1, 2, 3, 4, 5 but we suppose the draughtsman so to number them, and, if so, the points through which the curve will pass will be found at the intersecting points of the circles described from centre of *d* with the correspondingly numbered radial lines drawn from centre to the divisional points in semicircle *a h k*. Thus, the first point *l* is obtained by the intersection of the circle *e* 1 with the line *e* 1 (*e f*); the second point *m* is found at the intersection of the circle *e* 2 with the radial line *e* 2 (*e g*); the third point *n* by the intersection of the circle *e* 3 with the radial line *e* 3 (*e h*); the point *o* by the cutting of the circle *e* 4 with the radial line *e* 4 (*e i*); the point *p* by the crossing of the circle *e* 5 with the radial line *e* 5 (*e j*). The terminating point is at *k*, at the end of the diameter *a c k*. This will give one-half of the curve of the cam. The other half is obtained by the radial lines, as *g e*, being continued, as to beyond *u*, and the points will thus be as *q, r, s, t, u*. The cam, where the drawing is shown fully delineated, is furnished with voids or vacant spaces, as in fig. 1, Plate CCXVII., and fig. 1, Plate CXCV.

In fig. 1, Plate CCVI., let *a b c d* be the dimensions of the curve or the circle which limits the path of the cam or revolving part. The peculiarity of a revolving cam is that, if connected with a part having rectilineal motion, it will give that part an alternate to and fro or backward and forward motion, of a varying character as to speed. Let the "throw" or vertical rise and fall given by the cam be equal to the distance *c e*. Divide this into two equal parts in the point 11, and from 11 as centre, with 11 *e* or 11 *c* as radius, describe the circle *c* 4 *e*. Divide half of this, as *c* 4 *e*, into any number of equal parts, as eight in the diagram; and from points thus obtained, as 1, 2, 3, etc., draw lines perpendicular to the diameter, *c a*, of the large circle *a b c d*. A series of points will thus be obtained on the line *c e*, as 9, 10, 11, etc. Next, from the centre *f* of the large circle *a b c d*, with radii as *f* 9, *f* 10, *f* 11, *f* 12, *f* 13, *f* 14, describe a series of concentric circles as shown in the diagram. Next divide the circumference of the large circle *a b c d* into double the number of parts into which the semicircle *c* 4 *e* is divided. This will give sixteen points in *a b c d*. Through these points draw radial lines to the centre *f*. The intersection of these radial lines with the circles described from *f*, with radii as *f* 9, *f* 10, etc., will give a series of points through which a curved line

be drawn by hand. This curve will be the periphery or outside line of the cam, as required. Thus the intersection of the first circle, *f* 8, with the first radial line *f g* gives the first point 7; the intersection of the second circle, *f g*, with the second radial line *f h* gives the second point *s*; the intersection of the third circle, *f* 10, with the third radial line *f i* gives the point *t*; of fourth circle, *f* 11, with fourth line *f b* gives point *u*; the point in the fifth circle, *f* 12, with the fifth radial line *f j* the point *v*; the fifth circle, *f* 13, with fifth radial line *f k* the point *w*; the sixth circle, *f* 14, with sixth radial line *f l* the sixth point *x*, the last point being in the termination of the line *f a*. The curve drawn from the point *e* to *a* through the points 7, *s*, *t*, *u*, *v*, *w*, *x*, gives half the outline of the eccentric curve required. The other half is put in by finding points which correspond to those already found, these being at *y*, *z*, *a'*, *b'*, *c'*, *d'* and *e*. The student will perceive that the points, as *v* and *x*, are connected not by straight but curved lines. These are drawn with an accuracy proportioned to the number of points, as *v x*, etc., which are found. The greater the number of points the better; and therefore the greater the number of parts into which the circumference of the circle *a b c d* and the diameter *c e* of the smaller circle are divided, the more numerous will the points be. To prevent confusion, and to show the relation of the lines to one another, we have divided the circles in the diagram into as few parts as possible consistent with its accuracy.

Delineation of Mechanical Contrivances with Motion—The "Cam" (*continued*).

"Cams" are often used in the industrial arts, where stamping, pounding, or crushing of solid and hard substances is needed for one purpose or another. In the machines adapted to those processes the material is placed in a convenient receptacle, and a heavy pounder or ram is raised a certain height in the attached framing, and being released from the lifting appliance is allowed to drop or fall by its own weight upon the material which has to be broken up, crushed or pounded. The lifting appliance is a "cam," and the form or curve of the cam is that known as the "involute cam," the curve being based upon the "involute curve" (see "The Geometrical Draughtsman"), just as the "cams" in fig. 1, Plate CXXXIV., and fig. 1, Plate CXCV., in this present series, are based upon the curve of the "epicycloid" illustrated in The Geometrical Draughtsman."

In fig. 2, Plate CXXXIV., we illustrate an involute "cam," showing the method of applying the curve illustrated in "The Geometrical Draughtsman." To find its curve, let *a* be the centre of the shaft in which the cam is to be fixed, *a b"* the height through the stamper or crusher has to be raised, and through which it of course falls. Let *a o* be the generating circle of the curve, as described from centre *a*. Divide this into any given number of equal parts, as nine in the points *d*, *e*, *f*, *g*, *h*, *i*, *j*, *k* and *d*. From the centre *a* through these points draw radial lines as shown; and from the points *o*, *d*, *e*, etc., draw lines perpendicular or at right angles to the radial lines, as the line *d l* to the radial *a d*; *c m* to the radial *o a*, *e h* to the radial *e a*, *f o* to the radial *f a*, *g p* to the radial *g a*, *h q* to the radial *q a*, *i r* to the radial *r a*, *j s* to the radial *j a*, *k t* to the radial *k a*, and *k u* to the radial *k a*. Proceed now, as explained in connection with fig. 1 or fig. 2, Plate CXCIV., to find in those lines—as *d l*, *c m*, etc.—the points through which the curve is to pass. The curve begins at the point *d*; that farther in, joining the "boss" or "eye," *y y*, of the cam, is put in to give merely a symmetrical finish, as the stamper does not come in contact with this part. The first part of the true or working curve—namely, *d v*—is found by describing an arc from *c* as a centre, with *c d* as radius; the second part, *v w*, is found by describing an arc *v w* from the point *e* as a centre with *e w* as radius. By proceeding thus the points *o*, *p*, *q*, *r*, *s*, *t* and *u* are found, through which the curve may be drawn by hand or "set curve." Or by putting in the various lines, as *d v*, *v w*, etc., by the compasses, the curve will be more easily described, and accurately enough. The diameter of shaft is *a x*; the thickness of boss or ring of eye *x y*; the inner part of the cam is filled in with a web *z z*; the length of the cam, as from *o* to the point *t*, is found by taking *a* as a centre and *a b* as radius, and sweeping round as by the arrow *b'* to cut the line *j t*, or line of curve *t u* in the point *t*, which gives the extremity of the cam. This may be slightly rounded off, as shown. This point is connected with the "boss" or eye of the cam *y y* by a curved rib, as shown.

The length of the cam from *a* to *t* is dependent upon the radius of generating circle, as *a c*. If this was longer than *a c*, the length of cam would have been shorter, notwithstanding which the lift would have been the same, for the rise in the same length would have been greater. The angular space passed through by the cam would be in this case less, so that it could be worked at a higher velocity or speed, the stamper giving a greater number of blows in the same time; the power being, of course, proportionally greater than it would take to work the cam.

In fig. 2, Plate CCVI., we illustrate a method of finding the curve of a "cam" which gives an intermitting motion, but which motion is uniform during its stroke. The curve is that of an epicycloid. The motion which the cam gives to the part it actuates or works upon is stopped at each end of its stroke, the cam ceasing to act upon the part; but by its

continued revolution the working surface of the cam comes again in contact with the part to be moved, which is again put in motion with a uniform velocity or speed throughout its whole stroke; and again to have a pause at its termination when the acting part of the curve ceases to be in contact with it; yet again to be moved in the contrary direction when the acting part of the cam comes round in its continued revolution. By adjusting the curve, or rather the generating parts of it, the direction of the action of the cam may be greater than that of the pause or stoppage of motion at the end of the stroke of the moved part of the machine, or it may be less.

Let *a* be the centre of the shaft which is embraced by the eye or "boss" of the "cam." From centre *a* with radius *a c* describe a circle, as *c d e f g h*. Divide this circle into six equal parts in the points *d*, *e*, *f*, *g* and *h*, and join the first, as *d*, with the fourth, as *g*, by a radial line *g d*, passing through the centre *a*. Do the same at the second and fifth points *e* and *h* by a line *e a h*. It is within those angular spaces thus produced that the acting surfaces of the cam are placed, and within which the points are found by which its curves are obtained. The other spaces of the circle correspond to the periods of revolution of the cam at which its curved surfaces cease to act upon the part of the machine to be moved.

The intersection of these circles with the corresponding radial lines, as from 1, 2, etc, to *a*, will give points as *m*, *n*, *o*, etc. Thus, the intersection of the first radial line, as *k a*, with the first circle passing through *b*, will give the point *m*; the intersection of second line going from point *k*, as 4 *a*, with the second circle passing through point on line *b c*, will give the point *n*. The other points, as *o*, *p* and *q*, are found in the circles passing through the points *j*, *k* and *l*, cutting the radial lines 3 *a*, 2 *a*, and 1 *a*. From centre *b*, with radius *b i*, describe a circle which will give the outside point, *v*, of cam nearest the boss or eye. With same radius, as *b v* or *b i*, describe a series of circles—shown by arcs only in the drawing, to prevent confusion—from the points *m*, *n*, *o*, *p*, *q*, and *g*; these cutting the radial lines, as *k a*, 4 *a*, 3 *a*, 2 *a*, 1 *a*, and *g a*, will give points as *r*, *s*, *t*, *u*, *w* and *g*. These are the points through which the curve is to be drawn, terminating at point *g*. The other half, as from *v* to *y*, is formed in the same way. Fig. 2, Plate CCXVII., illustrates the way in which the cam may be finished, and also how the nature of the curve of the cam is varied, according as the conditions of its generation are changed.

Projection of the Development of Surfaces of Solid Bodies in the Constructive Arts.

We have now to direct the attention of the pupil draughtsman to a very important and very interesting and, to the thoughtful tyro in the art, attractive series of constructions useful in a wide variety of the work alike of those engaged in the various departments of building construction and of mechanical work. Those constructions or—to use the term more in accordance with the general principles upon which architectural and engineering drawing is based—projections are connected with what are called the geometrical solids, which the reader will find described in the latter part of the series of papers entitled "The Geometrical Draughtsman." The reader by referring to this paper will see explained the difference which exists between those geometrical solids and what are known as geometrical surfaces; a surface having two dimensions only, length and breadth, while a solid has three, namely, length, breadth or width, and thickness or depth. In the present series of papers the pupil has had projections and constructions and problems connected both with surfaces and solids: projection, indeed, properly considered, is the delineation of a solid body in such a way that its parts can be shown upon a flat surface, which a sheet of drawing paper on the surface of a drawing board or floor necessarily is.

But the projections hitherto given in the present series of papers have had reference to no special class of solids; examples having been taken just as they presented themselves as most readily adapted to explain the principles of projection we desired to communicate to the reader. But we are now about to introduce him to a special series of solids, upon which are based, as we have said, a variety of projections of the highest value to the constructor alike of buildings and of machines, with all their varied departments of work. The solids upon which those projections are based are the "cylinder," the "sphere" or globe, the "cone," and the "pyramid." The general features of these, along with those of other solids, will be found elsewhere in the latter part of the series of papers entitled "The Geometrical Draughtsman"; it is with those special characteristics on which the practical projections above referred to are based that we are now concerned.

The projections here alluded to are of two classes, dependent upon or connected either with the "development of the surfaces" or with the "sections" of the solids we have named above; although in some projections both the development of surfaces and sections are illustrated. What is meant by the expressions "development of the surface" of a solid or its "section" will be explained as we take up each development of projections based upon them.

Of the four solids we have named above we shall take the "cylinder" first. This may be briefly defined as a circular or round solid of uniform diameter having parallel sides, and terminated at its ends by circles the planes of which are exactly parallel to

each other. When the surface of a cylinder is "developed" a rectangular surface is formed, as $f g h i$ (see fig. 3, Plate CCXVII.), the height of which, $g h$, is equal to the length of the cylinder, which in the example, to save space, is equal to the diameter of the cylinder; and the length, $f g$ or $h i$, equal to the length of the circumference of the circle, as $b j c e$. The "development" of the surfaces of cylinders, or parts of cylinders,—either "right cylinders," as that in fig. 49 is called, in which the sides $a c$ or $b d$, and ends as $a b$ or $c d$, are both parallel to each other; or cylinders the end or ends of which are oblique, as the end $i j$ or $q r$, fig. 1, Plate CCXXXII, obtained by the cutting of their surfaces by lines in various positions,—is useful in a variety of operations connected with arches, groins, ceilings, staircases, etc., etc., and in the formation of many parts of mechanism, such as boiler plates, tubes, etc., etc.

Principle upon which the Development of Surfaces of Solid Bodies depends.

The principle upon which the development of a cylinder is based may be explained thus; and it may

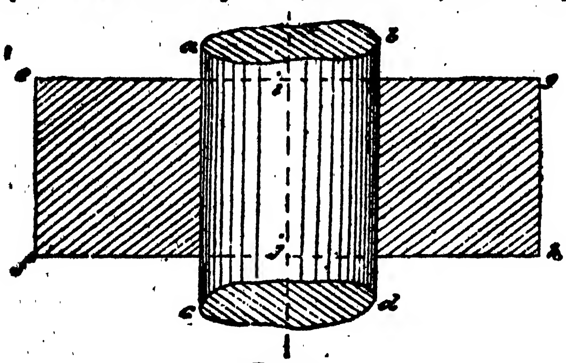


Fig. 49.

be here noted that, for the term development of surfaces of solids the expression "coverings of solids" is often substituted. Practically the two terms are synonymous. The latter term gives, perhaps, the most direct clue to the principle of this department of projection; for if the reader will conceive of any solid as being covered with any thin material or substance, as calico or paper, so that every part will be equally and tightly stretched out, so embracing the solid and giving a surface as smooth and unwrinkled as the surface of the solid in its natural or normal condition,—if he will further conceive of this tight covering given to the solid so put on that by cutting it at one point it can be taken off without in any way altering the form or lessening its extent,—and if when taken off it can be stretched out or extended upon a flat surface, as that of a table,—he will see in this extended piece of calico or paper that which represents in reality the surface of the solid round which it was originally wrapped or wound. If the reader will further consider this flat surface of calico or paper, he will be able to understand how it might be so refolded or handled that it would take the form, the exact form, of the solid round which it had been originally wrapped or wound. In other words, it may be said that the flat surface of paper is the surface of the solid stretched out before him. And by no great exercise of imagination he can conceive of every solid presented to him as being inclosed within a casing of some flexible material, which casing, if it could be taken off, could be extended on some flat body; and when so extended, the solid, in its original form having three dimensions, length, breadth and thickness, would now be represented by a surface having only length and breadth.

The pupil draughtsman, as he proceeds, will have examples shown him by which he will see the direct application of the principle of "development" here stated—a principle which embraces the converse of the process, namely, "envelopment"—but he will so far be able to see that in dealing with the solids the practical man will, in many of his operations connected with them, have great facilities offered him by this principle, which enables him to deal with solid bodies as if they were flat surfaces, and conversely with flat surfaces as if they were solids. Each solid has its own casing, so to say, or covering, which is capable of being extended or supposed to be extended so as to form a flat surface; and if by some means we can produce—in the draughtsman sense "project"—this flat surface, we can at will produce the solid body or deal with any part of it in a constructive sense. This extension of the casing, as we have called it, or covering with which we suppose every solid to be provided, into a flat surface, will so far explain the meaning of the term "stretch-out," which the pupil will find frequently used in the projections now to be illustrated and explained, and which is an equivalent or convertible term or synonym for the expression "development of the surface."

How this is obtained in the case of the cylinder we shall now proceed to explain, taking first into consideration the elementary diagram in fig. 1, Plate CCXXXII., which will give a graphic explanation of the principle of "envelopment," and its converse of development, as we have stated. Let $a b c$, fig. 50, be supposed to be a cylinder, of which the height is $a b$, the diameter $c f a g h$. It is here represented in isometrical perspective, but in plane projection it would assume the form of a simple rectangle, of which the distance $c h$ or $d i$ would represent the height of the cylinder, and the breadth $c d$ or $h' i$ the diameter. In place of supposing the solid cylinder, fig. 50 (next chapter) to be of wood, for example, we can suppose it to be formed of a long strip of paper wrapped so tightly round that it will be hard and firm.

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END OF VOL. IV.